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REDUCED PHYSICAL FIDELITY TRAINING DEVICE CONCEPTS FOR ARMY MAINTENANCE TRAINING

By Edwin P. Durall
William D. Spears
Wallace W. Prophet

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BY

SEVILLE RESEARCH CORPORATION
400 Plaza Building
Pensacola, Florida 32505

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Selected Army maintenance training courses were surveyed in terms of their training objectives, training practices, and use of training devices, particularly actual equipment trainers (AET). The objective was to identify areas in which the Army might cost-effectively substitute reduced physical fidelity (RPF) devices for AETs. Four major segments of Army institutional training of wheel and track vehicle and turret maintenance personnel are identified in which RPF devices might be cost-effectively substituted for AETs. Two RPF →

20. device concepts are described for use in teaching troubleshooting of engines and related systems; one RPF device concept is described for teaching troubleshooting of track/suspension systems; one RPF device concept is described for teaching removal/replacement of engines and power packs; and four RPF device concepts are described for teaching troubleshooting of turret electrical and hydraulic systems.

A general methodology for determining the training effectiveness of RPF devices is also presented. This methodology considers such aspects as the device's usefulness in a variety of training settings, its performance characteristics, and its measurement and feedback capabilities. Also described are the procedural steps involved in the evaluation effort and the types of expertise needed in conducting the evaluation.

SUMMARY

The purpose of this research effort was to develop conceptual descriptions for a variety of reduced physical fidelity (RPF) training devices that might be cost-effectively substituted for actual equipment trainers (AET) in selected areas of Army maintenance training. An associated task was to develop an evaluation methodology for determining the training effectiveness of the conceptual devices should they be developed and procured by the Army. The effort was focused on segments of Advanced Individual Training of wheel and track vehicle maintenance personnel and turret maintenance personnel.

The first area of activity involved identification of certain training requirement areas for which the Army might consider development of RPF alternatives to AETs. The second major area of activity was the development of conceptual descriptions of RPF alternatives for specific skill/task segments of maintenance training, while the third treated various considerations related to evaluation of the training effectiveness of any resultant RPF devices.

These activities resulted in identification of four segments of Army maintenance training in which cost-effective RPF/AET substitution might be made and conceptual descriptions of eight RPF devices to be considered for that substitution. Two devices are recommended for use in teaching troubleshooting of engines and related systems; one device is identified for teaching troubleshooting of track/suspension systems; one device is described for teaching removal/replacement of power packs; and four device concepts are presented for teaching troubleshooting of turret electrical and hydraulic systems.

A general methodology is then presented for determining the training effectiveness of any of the RPF devices which might be produced. This methodology considers such aspects as the device's effectiveness in a variety of training settings, its performance characteristics, and its measurement and feedback capabilities. Also described are the procedural steps for the evaluation effort and the types of expertise needed on the team conducting the evaluation.

PREFACE

This study was conducted under NAVTRAEQUIPCEN Contract Number N61339-77-C-0121 between the U.S. Army Project Manager for Training Devices and Seville Research Corporation. Dr. Wallace Prophet was Project Director for Seville, and Dr. Bernard Rashis was the Contracting Officer's Technical Representative. The Army Study Advisory Group (SAG) was chaired by MAJ Arnold Gaylor and, in addition to Dr. Rashis, included MAJ Harold Richardson, Mr. Glen Boquist, and Mr. Tom McNaney. The guidance and assistance provided by the SAG members are gratefully acknowledged.

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INTRODUCTION

The training of military maintenance personnel has received increasing attention in recent years. Four factors appear to be primarily responsible for this concern:

1. Modern weapons systems are becoming increasingly complex and sophisticated with resultant requirements for more highly skilled maintenance personnel.

2. Costs of training maintenance personnel have increased.

3. Costs of training aids and devices used in maintenance training are correspondingly greater as weapons systems increase in complexity and sophistication.

4. The relative effectiveness of training aids and devices currently used in maintenance training is uncertain.

Added to these four factors is a fifth overriding concern, the importance of maintenance to the operational capabilities of military units. In the total context, it is easy to understand this increasing attention upon maintenance training and the resultant efforts to reduce its cost, without sacrificing its quality and effectiveness, and to increase its effectiveness in skill shortfall areas.

There have been numerous efforts aimed at alleviating the difficulties underlying these concerns. For example, there have been attempts to produce hardware that requires less maintenance or can be maintained by less skilled personnel, but, while significant progress has been made in some instances, the trend toward higher skill requirements has continued. Concerted efforts have also been made to improve the training process itself. Perhaps the most significant of such efforts has been the development of the Instructional Systems Development (ISD) process [1/]. This systematic procedure begins with analysis of the actual tasks performed by military personnel on the job and identification of the tasks considered most critical to job performance. Institutional training is then focused on the more critical tasks, with the less critical tasks typically being assigned to on-the-job training (OJT). Elimination of noncritical material from institutional training usually results in shorter, less costly, proficiency-based courses, whose graduates are presumed to be more highly skilled in the elements considered crucial to optimum performance on the job. The ISD process, therefore, can have a direct and significant impact on the first two of the four concerns for military maintenance training listed above.

[1/] Interservice Procedures for Instructional Systems Development. TRADOC PAM 350-30, Headquarters, U.S. Army Training and Doctrine Command, Fort Monroe, Va., August 1975.

The latter two areas of concern regarding the cost and effectiveness of training aids and devices, particularly actual equipment used as training devices, are continuing problems and are the focus of the research effort described in this report.

MILITARY PROBLEM

The Army, like all the services, has become increasingly concerned with its maintenance training. Maintenance problems are compounded by the wide variety of equipment and vehicles peculiar to combat units and by the unfavorable field environment in which much Army maintenance necessarily takes place. Further, the new generations of Army weapons systems (e.g., the XM-1 tank) are costly and complex.

The teaching of maintenance tasks in the Army has traditionally been organized around a theory-first, practice-later paradigm. Also, the Army has generally followed the traditional practice of placing major reliance on the use of Actual Equipment Trainers (AET) [1/] as the principal vehicles for "hands-on" practice in training. Training has typically consisted of the presentation of important background knowledge through classroom lecture, followed by demonstration of the maintenance task by the instructor. Small groups of students then practice the task on an AET, and all members of the class cover the same material at the same rate. There are two significant disadvantages to this mode of instruction: (1) the instruction is generally aimed at the middle ability level of the class, thus frustrating both the higher-ability and lower-ability students; and (2) because they work in groups and all groups move at the same pace, not all students are able to practice all tasks on the equipment. In some cases, there is also reliance on paper-and-pencil tests to measure student proficiency. These tests measure the basic knowledge taught in the classroom reasonably well, but are weak as means of evaluating those portions of maintenance training that focus on physical manipulation of tools and equipment.

Consideration of these problems in light of extensive research into human learning and advancements in educational technology that have occurred over the last decade or two has brought about a fundamental change in military maintenance training philosophy. There has been a shift away from the lock-step approach in training toward an approach that emphasizes individualized instruction and employs such procedures as self-pacing, proficiency-based training, performance mastery, and the like. [2/]

[1/] The term AET refers to items of actual equipment that are used as training devices. AETs may be entire, end-item systems such as trucks, or they may be end-item subsystems or components such as truck engines. AETs may be whole, i.e., in operational form, or they may be modified for use as training devices (e.g., truncated, cut-away, and/or mounted on a platform).

[2/] Taylor, J. Establishing the Concepts and Techniques of Performance Oriented Training in Army Training Centers: A Summary Report. Technical Report 75-21, Human Resources Research Organization, Alexandria, Va., June 1975.

As would be the case in any sizable educational/training system, this change from lock-step to self-paced[1/] instruction has not come about without the occurrence of major problems. Significant among these are problems related to the AETs currently being used in maintenance training. In self-paced instruction, the individual student is required to demonstrate proficiency on each required task before advancing to the next task in the instructional sequence. The shift from lock-step to self-paced maintenance training, therefore, is placing greater and greater demands on AETs currently supporting the training. Many AETs cannot hold up under the increased usage and deteriorate rapidly. In addition, the task-oriented nature of self-paced training is creating a need for even more equipment to support this newer method of training.

As has been noted, AETs have traditionally been the mainstay among maintenance training devices, and their use has been predicated on a number of presumed advantages:

- they provide a high degree of face validity, or realism, to the student;
- they are usually readily available;
- they do not require large developmental costs or lengthy developmental cycles such as are sometimes associated with synthetic training devices; and
- items of equipment which have become unserviceable due to damage or age can be removed from the operating inventory and used as maintenance training devices at very low cost.

The first of these presumed advantages, provision of realism to the student, is considered by maintenance training personnel to be the most important. It is virtually a basic "article of faith" among most maintenance training personnel that the only effective way to teach most "hands-on" skills is through the use of actual equipment.

There are, however, a number of disadvantages to relying upon AETs as training devices:

- in the case of a new system (e.g., the XM-1 tank), there are no unserviceable items in the inventory, and expensive operational equipment must be tied up in supporting training functions instead of supporting the functions for which it was designed;
- AETs typically have few, if any, features included specifically to enhance the training process;

[1/] As used here, the term "self-paced" refers to an instructional program in which the student's day-to-day instructional events and pace at which he moves through the program are dependent upon the performance he exhibits. The term is not intended here to connote that necessarily the student chooses the pace as he pleases, though it is not incompatible with such choice.

- many AETs are carried on the inventory as training aids and do not receive the engineering changes that operational equipment receives through the Department of Army modification work order or product improvement program, thereby tending to become obsolescent and out of date;

- AETs usually provide little or no trainee response-measuring capability or means of providing feedback to the trainee;

- AETs have limited capabilities for malfunction insertion and/or demonstration of non-normal operation;

- AETs normally receive a low priority for repair parts and consequently, may be inoperable pending receipt of repair parts; and

- AETs often are limited to nondestructive uses of the equipment, thus restricting their usefulness in many training applications.

As can be inferred from these disadvantages, there have been serious questions raised about the use of AETs in terms of both cost and effectiveness considerations. For example, a turret for the XM-1 tank is an expensive item, and when modified for use as an AET its cost would be even greater. In spite of this cost, its utility in terms of training effectiveness and efficiency would still be limited. Further, the AET is often incompatible with the individualized, self-paced instructional approach toward which the Army is moving in its maintenance training.

Recent advances in training technology have produced a wide array of newer instructional media, media that are generally more compatible with the training methods now espoused by the Army. Included in their number are devices of reduced physical fidelity (RPF).[1/] Many of these devices incorporate such training-related features as automated performance measurement and immediate feedback to trainees, capabilities which AETs do not possess.

As a result of these factors and the Army's general concern for improving its maintenance training better to meet operational needs, the Army finds it must seek alternatives to AETs in many areas. This is not meant to suggest that actual equipment has no place in Army maintenance training, but that media alternatives (including AETs) must be examined in terms of their overall cost effectiveness in meeting maintenance training requirements as part of a total system approach. Thus, where AETs are uniquely suited to the training requirements, where they possess cost-effectiveness advantages, or where no alternative exists, they will continue

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[1/] RPF devices can be either two- or three-dimensional representations of actual equipment or systems within the equipment. These devices include a variety of trainers that usually display the system under study on a panel and are either hardwired or computer-controlled. Many are factory-programmed, but others may be programmed by the user. Drawings are normally used to show components, but some actual components may be used to attain a certain degree of realism.

to be the instructional medium of choice.[1/] However, in those areas where alternatives exist, or can be developed, and have cost and training advantages over the AET, it is prudent that the Army pursue such alternatives. Thus, the general military problem addressed in the research effort reported here is the role of AETs in Army maintenance training and the identification of alternatives to AETs that have promise of cost and/or training benefit.

RESEARCH PROBLEM

From the research point of view, the military problem described has several facets. First, what are the types of maintenance skills and knowledges for which training devices are or may be used? This requires behavioral/instructional analysis. Next, what are the different types of devices? The AET is the major device type used in maintenance training, but developments in training technology and simulation have led to development of a variety of RPF devices that are or can be used in maintenance training. Finally, how can the effectiveness of a given device in teaching specific maintenance skills and knowledges, or classes of such skills and knowledges, be evaluated?

The present research, therefore, has addressed three areas as they relate to Army maintenance training: (1) skill/knowledge definition; (2) device alternatives; and (3) device evaluation. The effort is part of the overall training device research program of the U.S. Army Project Manager for Training Devices (PM TRADE). The basic thrust of PM TRADE's efforts is the development of more effective devices for the Army, devices that allow achievement of necessary training goals at minimum cost. The research aim has been the identification and conceptual description of potentially cost-effective alternatives to AET devices for use in selected areas of Army maintenance training and development of a methodology for evaluating such alternative devices.

ORGANIZATION OF REPORT

The main thrust of the effort reported here has been the development of conceptual descriptions of RPF devices. Therefore, the emphasis in the main body of the report will be on these RPF concepts and the general areas of training to which they are addressed. The bulk of the detail relating to the various tasks or activities that underlie the RPF concepts is relegated to the various appendixes.

The report is comprised of four sections, including the present introduction. In the second section the general approach followed in the overall effort is described in terms of the specific research tasks that were involved. However, much of the detailing of these tasks is covered in the appendixes. Section three describes the various areas of training of principal concern and presents a description of the various RPF concepts developed. It also includes a discussion of a device training effectiveness evaluation methodology as developed in the present effort. Finally, the

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[1/] AETs may be used in conjunction with RPF devices to facilitate the transition to actual equipment.

fourth section presents a discussion of Army maintenance training and AET and RPF device requirements. The appendixes to the report are referenced as appropriate in the main text.

II. APPROACH

GENERAL SCOPE

The basic goals of this effort have been to identify areas in which RPF substitution for AET devices might be considered, to specify the conceptual form for such RPF devices, and to provide procedural guidance for the future training effectiveness evaluation of such RPF devices should they be developed to the point of prototype fabrication. In pursuit of these goals, a systematic procedure has been followed in which current Army maintenance training programs were examined and certain device requirement areas identified. The approach has involved a combination of survey analysis, rational analysis, and professional judgment based on empirical data wherever possible.

The first major research activity in the effort required identification of training requirement areas for which the Army might reasonably consider development of RPF alternatives to AETs. The second major area of activity was the development of conceptual descriptions of such RPF alternatives, while the third treated various considerations pertinent to evaluation of any resultant RPF devices with reference to training effectiveness.

PROJECT TASKS

The accomplishment of the objectives of the three areas of project activity just described required that six specific research tasks be executed. The first two tasks concerned the first area, i.e., identification of the maintenance training areas of primary concern to the Army in the present context. The second area (development of RPF conceptual descriptions) also involved two specific tasks, while the third area involved a single task. In addition, a sixth research task concerned with reporting was carried out, but it dealt with all areas of project activity.

Throughout the effort, guidance was provided to the Seville project team by an Army Study Advisory Group (SAG). The SAG consisted of representatives from the Army Training and Doctrine Command (TRADOC), as well as representatives of PM TRADE. Through a series of meetings and interim reports by the Seville team, the SAG was kept informed of project activities and plans and was able to provide technical guidance to the research team on a regular basis. Prior to initiation of the first task, Seville personnel were required to present to the SAG a detailed plan for execution of the six tasks, and, in fact, certain revisions to the plan were made as a result of this interaction. It should also be noted that the SAG played an active role in making some of the arrangements for training site visits made by the research team.

As noted, six specific tasks were formulated for achievement of the overall research objectives. The six tasks were as follows:

1. Investigation of Use of AETs in Maintenance Training

2. Identification of Potential AET Replacement Areas

3. Evaluation of Existing RPF Alternatives

4. Development of New RPF Concepts

5. Development of Training Effectiveness Evaluation Requirements

6. Reporting

General descriptions of the six tasks follow, and additional details are given in the various appendixes.

Task 1 - Investigation of Use of AETs in Maintenance Training

The general objective of Task 1 was to determine the nature of Army maintenance training, its objectives and organization, and the actual uses being made of AETs and other devices in that training. The principal research activity involved was a survey of the use of AET devices in the institutional training of Army personnel to maintain track and wheel vehicles, including maintenance of turrets. Advanced Individual Training (AIT) courses for both organizational and DS/GS level mechanics were included (see Appendix A). Some twelve different MOS-producing maintenance courses at three major Army training centers were surveyed. The survey was designed to determine the nature of skills taught, the general organization of the courses of instruction, the AETs and other devices used to support instruction, and a variety of other relevant factors such as training schedules, student input/output flow, equipment costs, and the like.

Survey of the practices of non-Army counterpart maintenance training programs was also conducted in Task 1. This survey touched on the programs of the other military services, as well as selected nonmilitary agencies.

Further details of the surveys, including survey procedures, interview guides, and sites and persons surveyed, are given in Appendixes A and B.

Task 2 - Identification of Potential AET Replacement Areas

The objective of Task 2 was to identify those areas of AET usage in Army vehicle maintenance training for which an RPF alternative might be cost effectively substituted. Since Tasks 3 and 4 required the identification or development of RPF alternatives to specific AET devices or classes of devices, it was necessary that such efforts be reduced to a size that was manageable and feasible within the resources available to the present study. This required development of a schema for establishing an ordering of priority for the investigation and development of potential RPF devices to be used in lieu of current AET devices. The training survey data from Task 1 provided the input information for Task 2.

In order to establish the necessary priority listing, two things were done. First, the various training courses surveyed were examined to identify major or common content areas of concern. This resulted in identification of some 24 major training areas. Typical examples of such areas include: motor tasks in power plant maintenance by organizational mechanics; cognitive tasks in power train maintenance by DS/GS mechanics; and troubleshooting tasks in turret maintenance by organizational mechanics.

The second activity in this task was to develop and apply a rating schema to the 24 training areas in order to establish priorities for possible AET replacement. The concern here was to identify those areas of greatest training need or greatest potential cost benefit for the Army. In this regard, six dimensions were identified as of primary concern:

- Skill complexity
- Subject-matter difficulty
- Commonality to other courses
- Trainee volume
- AET instructional utility
- AET cost

The research team, based on the Task 1 data and experience, rated the programs on the above dimensions and recommended to the SAG four principal training areas for concentration of effort in developing RPF alternatives during Tasks 3 and 4. Definitions of the six scale dimensions and the rating procedure are contained in Appendix C, along with results of the rating procedure.

Task 3 - Evaluation of Existing RPF Alternatives

On the basis of the survey data (Task 1) and the high-interest training areas identified (Task 2), existing RPF alternatives to AETs were examined for possible development by the Army. These alternatives were examined in terms of their cost effectiveness as possible substitutes for AET devices found to be currently in use in Army training.

To supplement the survey data developed in Task 1, two additional sources were surveyed during Task 3. First, some 75 commercial training equipment manufacturers were contacted concerning possible RPF devices they might know of or which they might be producing. Second, various military research agencies conducting research on training devices were contacted concerning their research on or knowledge of existing RPF devices. These agencies included the Army Research Institute, the Naval Training Equipment Center, and the Air Force Human Resources Laboratory.

Task 4 - Development of New RPF Concepts

The objective of Task 4 was the development of new RPF conceptual approaches for the training areas identified in Task 2. While the approaches were not to be constrained by current practices, it was desired that the concepts to be described be feasible of accomplishment with a reasonably high probability of success. Thus, emphasis was on concepts involving extensions of existing technologies, or new combinations thereof, rather than on the development of completely new technological approaches.

In developing these new conceptual approaches, particular attention was paid to training areas for which no existing RPFs were found in Task 3 and those in which AET costs were high and/or AET training effectiveness was low.

Task 5 - Development of Training Effectiveness Evaluation Requirements

The focus of this task was the development of a procedure or methodology to provide guidance for the training effectiveness evaluation of any RPF devices that might eventually result from Tasks 3 and 4. Inputs into the development of the evaluation procedure derived from several sources. The principal sources were the general technologies dealing with evaluation design and with performance measurement. Another major source was the information developed in Task 1 concerning the nature of Army maintenance training in the various areas of concern. An additional input was based on general experience of the Seville project team and other research/evaluation personnel familiar with the evaluation of training devices.

Task 6 - Reporting

The conduct of this task involved a series of oral reports to the SAG, detailing activities on the various tasks in the overall effort, and the present report, which is the final activity of this task. The principal objectives of this report are to document the overall activities of the effort, to describe the RPF alternatives that can be considered for future development by the Army, and to set forth a procedure for their evaluation.

The frequent interactions between the research team and the SAG were essential not only for general information flow, but they provided a series of decision mechanisms with reference to the specifics of implementing the general research plan for the effort.

APPROACH SUMMARY

The six tasks described were aimed at satisfying the three general research objectives of identifying the high-interest or high-value training areas for possible RPF development, describing RPF devices appropriate for those areas, and developing a procedural guide for the training effectiveness evaluation of any such RPF devices that might be developed by the Army.

III. RPF ALTERNATIVES AND EVALUATION

This section of the report, organized into four general parts, details the various RPF alternatives developed in Tasks 3 and 4 and presents an overview of the training effectiveness evaluation procedures developed in Task 5. The first part describes the four Army maintenance training areas that were identified in Task 2 as being the high-interest areas with reference to possible device alternatives to AETs. The second and third parts describe the RPF device concepts, both the currently existing RPFs and the new conceptual approaches. The final part of this section then treats the concept of device training effectiveness evaluation.

HIGH-INTEREST TRAINING AREAS

As previously noted, in Task 2 the 24 different major training areas or domains were rated on certain dimensions in order to identify the training areas of greatest interest to the Army with reference to possible AET replacement. The four training content areas recommended to the SAG for further consideration (and subsequently approved by the SAG) were:

1. Troubleshooting Engines and Related Systems at the Organizational Level

2. Troubleshooting Track Vehicle Track/Suspension Systems at the Organizational Level

3. Removal/Replacement of Engines and Power Packs at the DS/GS Level

4. Troubleshooting Turret Electrical and Hydraulic Systems at the Organizational and DS/GS Levels

The first three of these areas are the responsibility of wheel and track vehicle mechanics, while area four is the responsibility of the turret mechanic. In order to provide some background for the RPF device descriptions, each of these training areas will be discussed in terms of the general maintenance tasks the mechanic must perform and the general manner in which training for those tasks is given. The distinction between organizational and DS/GS maintenance levels is of some importance to the discussion. These levels are discussed and defined in Appendix A.

1. <u>Troubleshooting Engines and Related Systems at the Organizational Level</u>

The troubleshooting activities of organizational wheel and track vehicle mechanics primarily involve determination of a vehicle's operational readiness and serviceability. In regard to a vehicle's engine, this involves performing a number of preoperational checks of the engine, its components, and related systems. The mechanic assures the engine starts quickly, its components are installed and operating properly, belts are at proper tension, fluids and lubricants are at correct levels, and performs a number of other rather superficial checks. If trouble symptoms appear, the organizational mechanic is required to identify the malfunction that caused the symptom to appear and to repair it if it is within his authorization to do so. As an organizational mechanic, his authorization is only to the component or subassembly level, meaning he can remove and replace a starter, for example, but is not authorized to repair the internal parts of the starter. That function is served by the DS/GS repairman.

The organizational mechanic is confronted with a vast array of wheeled and tracked vehicles encompassing a wide variety of gasoline, diesel, and multifuel engines. In addition, each type of engine is supported by its own unique charging, cranking, ignition, and fuel systems, thereby creating a formidable array of tasks for the organizational mechanic. To support its large inventory of vehicles, the Army is required to train great numbers of organizational mechanics. The four organizational maintenance courses observed in this study (62B10, 62B20, 63B10, 63C10) graduate approximately 10,000 trainees annually, with 60% of that total coming from the 63C10 (Track Vehicle Mechanic) course.

Because of the wide array of engines and related systems to which the organizational mechanic is exposed, approximately one-third of the training time in the four courses is devoted to the trainee being exposed to a great deal of theory regarding the function and operation of engines and related systems. The trainee also practices a number of physical skills requiring manipulation of tools and equipment, and learns to operate several types of diagnostic and testing devices, including the tach/dwell meter, low voltage circuit tester (LVCT), and multimeter.

The instruction for this segment of training begins with an introductory lecture by one or more instructors. Trainees usually attend this introduction in groups, since even in a self-paced course the trainees tend to work together in groups. In lock-step instruction, of course, the entire class is present. After the instructor explains the objectives, instructional procedures, and grading methods for the segment of training, the trainees move to the equipment to perform the tasks specified in the lesson guide. The instructors move about assisting the trainees where needed.

Troubleshooting of gasoline engines and related systems is usually taught using Jeep and other small truck engines as AETs, most of them still being mounted in the vehicles. Troubleshooting of diesel engines and systems is usually taught using actual engines mounted on stands. Engines from a number of manufacturers (primarily Cummins, Caterpillar, and Continental) are used in this training to expose the trainee to the variety of engines he might be required to maintain in his unit assignment. The engines mounted on stands, of course, require elaborate systems for provision of fuel and for removal of exhaust emissions. Since as many as 20 engines might be located in one shop, it is also a high-noise area, and trainees and instructors are required to wear protective devices over their ears.

Before an engine is started, the trainee makes a number of preoperational checks. These checks vary with the type of engine (gasoline, diesel, or multifuel), but generally include: belt tensions and condition; hose condition; fluid and lubricant levels, including battery and radiator; and the condition and general serviceability of the carburetor, fuel pump, throttle linkage, distributor, ignition wires, spark plugs, and exhaust system. Once the engine is running, a number of more complex tests can be performed, including: tests of various vacuum systems; checking of the timing; checking engine idle speed and point dwell using the tach/dwell meter; and various checks of the generator and voltage regulator using the LVCT and multimeter.

The training for these tasks involves the trainee performing the tasks, with assistance from the instructor if needed, using the proper tools, test equipment, and maintenance procedures as specified in the appropriate technical manual(s) (TM). The engines are usually in normal operating condition during this phase of training, and the trainee is therefore generally exposed to only normal conditions and test readings. As the trainee performs each task, he receives a "go" or a "no-go" from the instructor. A "no-go" usually requires the trainee to repeat the task or a certain portion of the task until the instructor is satisfied with his performance.

Upon completion of each set of tasks (i.e., upon receiving a "go" on all, or a certain percentage of, the tasks from the instructor), the trainee is subjected to a performance examination. In this examination, he is directed to an actual engine which the instructor has "bugged" through insertion of a number of malfunctions. A certain time limit is established, and the trainee must locate and repair all the malfunctions, thus returning the engine to normal operating condition. However, the number and variety of malfunctions to which the trainee is exposed are limited both by time and the difficulty of "bugging" the AETs.

2. Troubleshooting Track Vehicle Track/Suspension Systems at the Organizational Level

This area of troubleshooting by an organizational mechanic involves identifying the causes of malfunctions and determining the serviceability of the various torsion bars, lockout cylinders, support rollers, road wheels and arms, and other components of tracked vehicle track/suspension systems.

Troubleshooting of track/suspension systems involves direct observation of trouble symptoms such as leaking seals and cylinders, worn bushings, and a thrown track. This area of troubleshooting, therefore, is not as complex as troubleshooting of engines, but is identified as a high-priority area for RPF-AET substitution primarily because of extremely high AET costs. A second selection factor is, due to the cumbersome nature of the equipment, the inability of track/suspension system AETs to present a variety of malfunction symptoms without an inordinate amount of instructor set-up time or requiring a large number of AETs, each with a different set of malfunctions. Training in this skill follows the same general rubric described earlier. If trouble exists in a track/suspension system, the symptoms are quite obvious. For example, misalignment of the road wheels or center guides produces evidence of wear in specific spots. Broken torsion bars or leaking shocks might cause the vehicle to sag to one side. Since the symptoms are more obvious and the related causes fewer in number than in many other areas of troubleshooting, the instruction for this skill consists mainly of description and observation of the various symptoms and their causes. AETs are used to demonstrate some of the malfunctions, but the capability of an actual track/suspension system to present a variety of symptoms is severely limited. As in the previous section, the trainee is not able to observe a large portion of possible malfunctions until he works on the performance examination, where he is exposed to operational vehicles which exhibit a variety of symptoms.

3. Removal/Replacement of Engines and Power Packs at the DS/GS Level

This is a motor task involving disassembly of linkages and lines attached to a wheeled vehicle or tank engine or power pack (engine and transmission as one unit), removal of the engine/power pack, its reinstallation, and reassembly of linkages and lines. It is recommended as an area for RPF-AET substitution primarily because of AET cost. Entire vehicles are devoted to teaching this task where alternatives could be devised to reduce costs.

Training on this task, following the same general outline described earlier, consists first of instruction in disassembling the numerous fuel lines, electrical leads, hoses, and throttle linkages attached to the engine. If the engine alone is to be removed, the clutch must be disconnected. In power pack (engine and transmission) removal, the transmission must be disconnected from the propeller shaft and the transmission linkages disassembled. Mounting bolts are then removed. At this point, a sling is placed around the power plant, and an overhead crane or wrecker is used to lift it from its compartment. During installation, the procedures are reversed. The trainees must work in teams in performing this task.

4. Troubleshooting Turret Electrical and Hydraulic Systems at Both Organizational and DS/GS Levels

Troubleshooting, as described earlier, involves analysis of trouble symptoms and diagnosis of malfunctions that cause the trouble symptoms to appear. As such, troubleshooting is a difficult skill to master. In troubleshooting the electrical and hydraulic systems in the modern turret, however, the task is made even more difficult because of the sophistication of the two separate systems and complexities introduced when both systems are required to interact in performance of a number of functions within certain turrets. It must also be noted that from an instructional point of view, because of lack of space and poor visibility, the turret is not a good teaching device. For these reasons, and because turrets are very high-cost items, this area of maintenance was identified as having high potential for cost-effective RPF-AET substitution.

At both maintenance levels, troubleshooting of turret electrical and hydraulic systems involves use of a number of test devices such as the multimeter and LVCT to trace malfunctions. The trainee must also be able to trace circuit diagrams to know where to start testing. When a reading has been taken, that reading must be interpreted and the malfunctioning component identified. At this point, the organizational mechanic removes the component and replaces it with a new or rebuilt one. The DS/GS repairman is further confronted with the task of disassembling the component, repairing/replacing the malfunctioning part(s), and reassembling the component. Emphasis is placed here on electrical and hydraulic systems because the major systems in turrets are either all electrical (in the M551) or combinations of electrical and hydraulic components (in the M60 series and in the new XM-1). Skills in working with electrical and hydraulic systems, therefore, are necessary if the mechanic is effectively to maintain the current inventory of turrets.

Following the same training format as the other areas of instruction, training in this skill area centers primarily around malfunction detection through observation of readings on certain test equipment. This is particularly true for the electrical system, and the LVCT and multimeter are vital tools to the turret mechanic. By connecting the test instruments to test points associated with system components, certain values which register on the test equipment indicate certain malfunctions. In working with hydraulic systems, pressure measurements are important, as is visual inspection for fluid leaks.

Upon identification of the malfunctioning component, the skill of physically removing the component and replacing it with a new or rebuilt one is called into play. Tool selection and use, therefore, is another important skill that is taught.

As mentioned earlier, the DS/GS repairman is then faced with the task of disassembling the component, going through further troubleshooting procedures to isolate and replace the defective part, reassembling the component, and then testing it to assure it is functional and can be returned to stock.

EXISTING RPF ALTERNATIVES

As the present effort was originally conceived, Task 3 was to involve an assessment of RPF devices presently in use in maintenance training. Such devices, if they could be shown to be cost-effective substitutes, might then be considered by the Army as alternatives to some of the AET devices currently in use, particularly those AETs of high cost or low training effectiveness.

In point of fact, the only RPF devices found to be in current use [1/] that might be considered as alternatives to AETs were the so-called flat-panel systems simulators (FPSS). These devices are used primarily in teaching system troubleshooting tasks in maintenance training and in teaching procedural tasks for operator training. Such devices are little used for the teaching of the motor and cognitive tasks of concern in the present study, but are beginning to be used for some aspects of engine troubleshooting.

With reference to available information concerning the cost effectiveness of existing FPSS devices, an examination of the few studies that have been done reveals little or no valid cost-effectiveness data. In certain uses (e.g., with complex electronics and radar systems) the FPSS has been judged cost effective, but largely on the basis that the AETs are very high-cost items. No credible data were found to demonstrate FPSS cost and

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[1/] This statement is made in the context of the Army and non-Army training courses surveyed in Task 1 and the 75 manufacturers surveyed in Task 2.

training effectiveness in the vehicle/mechanical maintenance areas of concern in the present effort.[1]

As a further possible means of developing cost effectiveness data on these FPSS devices in the wheel and track vehicle maintenance areas, the TRADOC Systems Analysis Activity (TRASANA) was contacted concerning possible applications of its Cost and Training Effectiveness Analysis (CTEA)[2] model to such devices. TRASANA reports no knowledge of CTEA application to FPSS devices. In similar fashion, the Army Research Institute (ARI) was contacted concerning applications of the training device cost effectiveness determination procedure (TRAINVICE)[3] they have developed. This too failed to produce data concerning FPSS devices in wheel and track vehicle maintenance.

Thus, no direct data base could be assembled to substantiate the training effectiveness of the FPSS devices in wheel and track vehicle maintenance training, nor were there any sound, systematic cost effectiveness data relating to FPSS use in any setting. With reference to the four high-interest training areas identified herein, however, one must view the FPSS devices as potentially useful devices for AET substitution in

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[1] See, for example:

Biersner, R. Attitudes and Other Factors Related to Aviation Maintenance Training Effectiveness. CNETS Study Report No. 6-75, December 1975.

Biersner, R. Observations of the Use and Evaluation of ECII-LP Simulators for Aviation Training. CNETS Report No. 2-76, October 1976.

Darst, H. Evaluation of ECII Simulator. Research Memorandum No. 9-75, U.S. Army Transportation School, Fort Eustis, Va., 18 December, 1974.

Finch, C. and O'Reilly, P. The Role of Dynamic Simulation in Teaching Complex Problem-Solving Skills in Vocational and Technical Education. Educational Technology Research Series No. 56, Educational Technology Publications, Englewood Cliffs, N.J., 1973.

McGuirk, F., Pieper, W. and Miller, G. Operational Tryout of a General Purpose Simulator. Technical Report 75-13, U.S. Air Force Human Resources Laboratory, May 1975.

Wright, J. and Campbell, J. Evaluation of the ECII Programmable Maintenance Simulator in T-2C Organizational Maintenance Training. Naval Air Systems Command Report No. NADC-75083-40, 15 May, 1975.

[2] U.S. Army. Cost and Training Effectiveness Analysis Handbook. TRADOC PAM 71-10 (Draft), Headquarters, U.S. Army Training and Doctrine Command, Fort Monroe, Va., 3 January, 1977.

[3] Narva, M. Project Summary: Training Device Concept/Prototype Validation System (TRAINVICE). U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, Va., April 1976.

areas 1 and 4 (i.e., troubleshooting engines and turret electrical and hydraulic systems). Their utility in area 2 (troubleshooting of track/suspension systems) would be less likely, and they would likely have none at all in area 3 (removal/replacement of engines and power packs).

Perhaps the biggest area of concern in the use of FPSS devices to replace AETs in any of the four high-interest areas would be their general inability to present certain hands-on instruction n tasks such as remove/install, adjust, and other largely motor tasks. These actions, sometimes required during troubleshooting and usually as a consequence of diagnosis (i.e., executing corrective-action tasks), are viewed as important by maintenance personnel and represent an important area of AET capability and attractiveness.

To summarize, FPSS devices do represent alternatives to AETs in selected aspects of Army vehicle maintenance training. The existing data, however, do not fully support a current recommendation that they be procured for such substitution, though a recommendation that the Army conduct a systematic, empirical cost effectiveness evaluation of their use in vehicle maintenance training would be in order.

NEW RPF CONCEPTS

In considering new maintenance training devices of a conceptual nature that might be developed on an experimental basis, recent advances in training technology must be kept in mind. FPSS devices are capable of providing training in troubleshooting that has frequently been considered effective, but as described above, studies concerning the effectiveness of these devices are lacking in specific cost-effectiveness data. There is no question, however, that the capability of these devices to provide instruction in the decision-making and procedural processes involved in troubleshooting is far beyond that of AETs. A significantly greater number of malfunctions can be presented to trainees in a fraction of the time it requires an instructor to "bug" actual equipment. Numerous research studies have indicated, moreover, that reduced fidelity devices, even such low-fidelity devices as cardboard mock-ups, are very effective in teaching decision-making and procedural processes. 1/ These are the subordinate skills, mostly cognitive and internal, that are the dominant elements in the skill of troubleshooting.

1/ See, for example:

Cox, J., Wood, R. Jr., Boren, L., and Thorne, H. Functional and Appearance Fidelity of Training Devices for Fixed-Procedures Tasks. Technical Report 65-4, Human Resources Research Office, Alexandria, Va., June 1965.

Grimsley, D. Acquisition, Retention, and Retraining: Group Studies on Using Low-Fidelity Training Devices. Technical Report 69-4, Human Resources Research Office, Alexandria, Va., March 1969.

Prophet, W. and Boyd, H. Device-Task Fidelity and Transfer of Training: Aircraft Cockpit Procedures Training. Technical Report 70-10, Human Resources Research Organization, Alexandria, Va., July 1970.

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Instruction in the internal aspects of diagnosis and troubleshooting is important, but training in the hands-on aspects of these maintenance tasks should also be presented. Most of the new devices discussed in this section of the report make an attempt to bridge the gap between these two conceptual positions and provide training in both areas.

A hybrid training device, i.e., a combined FPSS and three-dimensional mockup, is one possible general solution to the hands-on/simulation dilemma. Combining the capability of the FPSS device to provide instruction in diagnostic aspects of maintenance with the ability of a three-dimensional mock-up to provide a variety of hands-on experiences, would extend the range of maintenance tasks that could be taught far beyond that present in current FPSS devices or AETs. This would generate cost savings in at least two categories, the first being decreased dependence on expensive AETs. The second and more significant category of potential cost savings would arise from developing improved maintenance skills within the trainees, thus increasing their efficiency and reducing equipment downtime. The devices suggested herein would allow repeated practice on a wider range of tasks than is possible in present training, and would play a significant role in these two areas of cost avoidance.

The conceptual descriptions of new RPF devices that follow are grouped in terms of the high-interest training areas previously discussed. Two devices are presented for area 1, one device for area 2, one for area 3, and four devices, or options, are presented for area 4.

Troubleshooting Engines and Related Systems at the Organizational Level

Two different types of devices will be discussed in relation to teaching this skill. Device 1 is a microprocessor-controlled mock-up engine with an attached FPSS, while Device 2 is a three-dimensional mock-up of a basic engine block to which would be attached electronic modules that are replicas of each of the various engine components. Each of these devices is discussed in more detail in the following paragraphs.

Device 1. This device would be composed of two separate components, a three-dimensional mock-up engine an an FPSS. These components would be interconnected electrically so that ne engine would be under control of the simulator. Thus, when the trainee performs a task, the results of that task, indicated by various symptoms or readings, would be displayed on the simulator panel. The two major components would be located in close physical proximity, perhaps on an L-shaped table. Figure 1 illustrates this concept.

The engine portion of the device would be a three-dimensional representation of an engine with its components such as starter, generator, carburetor, etc. In order to accommodate for the differences in design and operation of each engine type, a different mock-up engine and simulator would need to be manufactured for gasoline, diesel, and multifuel engines. A variety of hands-on tasks such as adjusting the fuel mixture and setting the idle speed would be practiced on this device, but the simulated removal and replacement of major components would be accomplished by pressing a button on the simulator. This action would indicate to the computer that the component had been replaced.

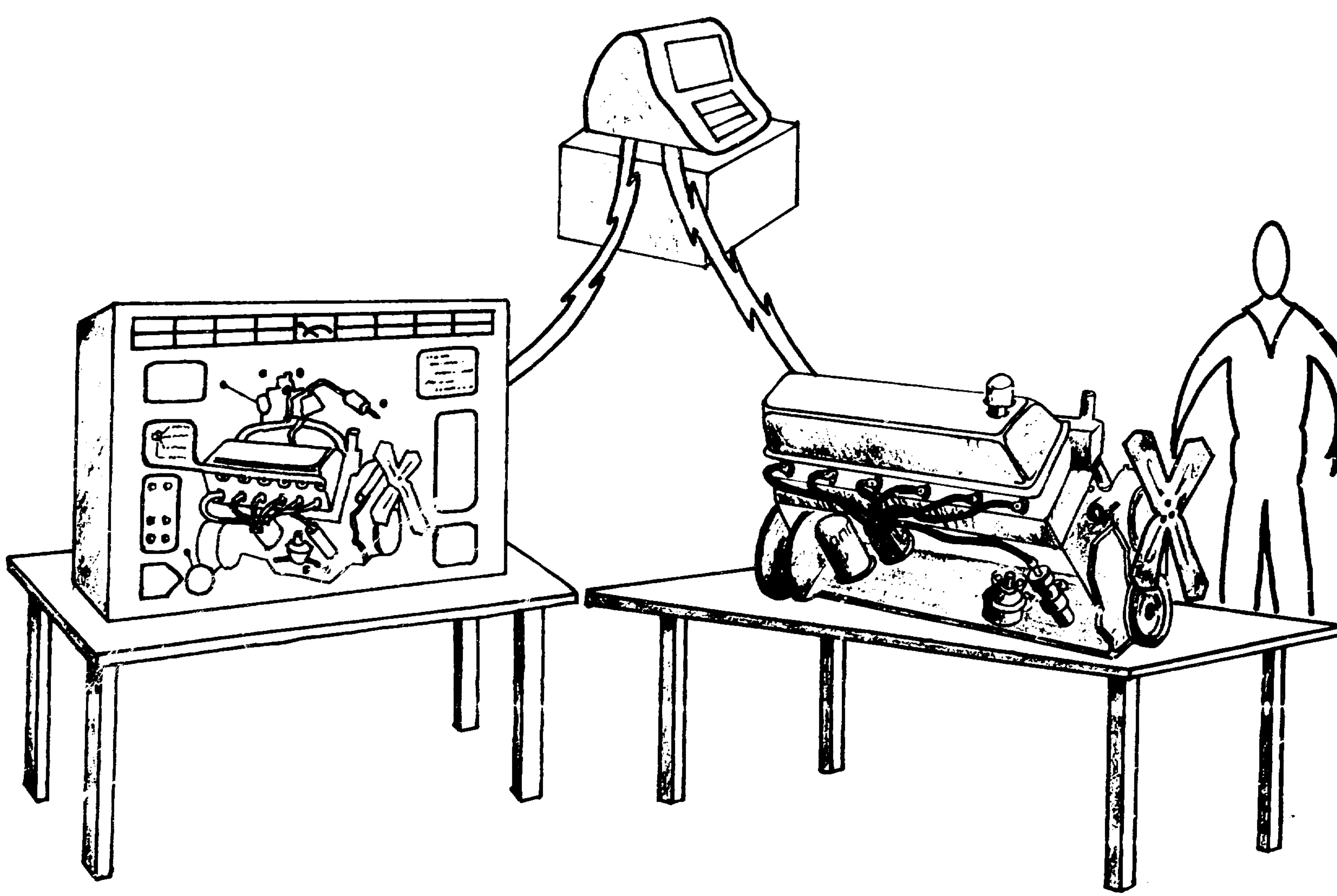

Figure 1. Engine Troubleshooting Device 1.

A high degree of simulation of engine operation could be attained through making the engine "run" by means of an electric motor. Many functions could be simulated, including the capability to make the engine vibrate by means of a weighted wheel in order to simulate missing, rough idle, etc. The computer-controlled electric motor could also drive elements which could automatically cause the fuel pump to fail, the choke to stick, or create other operational malfunctions.

The engine configuration would include all the external components and linkages, including starter, generator, accelerator linkage, etc., of an actual engine. This would allow the trainee to hook up simulated test equipment, make adjustments, and complete most of the tasks performed on a real engine short of the actual remove/replace tasks. The internal components of the engine would be pictured through the visual capabilities of the FPSS.

The technology for the FPSS component of this proposed device is in existence on a variety of trainers currently available from training device manufacturers. This would include the capability to present error messages, display pictures of engine components, display diagrams of engine-related fuel and electrical systems, provide test points and/or buttons, and provide remove/replace buttons. Simulated test equipment such as a tach/dwell meter, LVCT, and multimeter would also be included, as well as functional dashboard instruments. The entire device would be controlled from an instructor's control panel incorporated at a convenient location on the FPSS.

In providing instruction in [illegible]ne troubleshooting, the device would need to display a variety of [illegible]nction symptoms. For example, if a carburetor is set too lean a vib[illegible]on is caused by fuel starvation. This vibration could be simulated by a weighted wheel driven by an electric motor. A fuel mixture needle would be provided on the mock carburetor, and the trainee would "adjust" the fuel mixture as he would on the real engine, thus causing the simulated engine vibration to disappear. In the same manner, fouled spark plugs, clogged fuel filters or lines, and a number of other malfunctions could be simulated. The appropriate maintenance or repair action would be simulated by the trainee through pressing specific repair or remove/replace buttons on the FPSS.

A second general example of malfunction symptoms would be those which are indicated by various items of automotive test equipment. A specific instance would be improper point dwell as indicated by a simulated tach/dwell meter located in the FPSS panel. When an improper dwell angle is observed, the trainee would make the proper distributor adjustment on the mock-up engine. Other malfunctions identified by test equipment readings would include improper engine timing and excessive resistance in spark plug wires.

Finally, many of the cues needed by a mechanic to isolate malfunctions are cues provided by engine sounds. These include the hissing of a leaking vacuum hose, clicking or tapping noises, and a variety of other sounds. In order for sound cues to be effective stimuli for instruction, however, they must be generated so the trainee can locate and isolate them. Appropriate sounds of engine trouble could be reproduced and broadcast through small speakers placed at strategic locations throughout the mock-up engine.

Repair or remove/replace buttons on the simulator panel would allow the trainee to demonstrate his knowledge of the appropriate response to a sound cue.

Use of this device in teaching troubleshooting of engine and related systems would alter somewhat the current role of the instructor, and two noticable changes would be evident. First, the large block of time now required to insert malfunctions into AETs would be reduced to the few seconds it would take to set the malfunction selector on the instructor's control panel. In addition, as soon as the trainee identifies a malfunction and takes the proper action via response button or physical action, another malfunction can be selected. The trainee can thus be exposed to a large number of malfunctions and responses in a short period of time, a flexibility and range of instruction which is not possible with an AET.

The second major change in the instructor's role would come from the device's assumption of portions of the direct instruction. This would free the instructor from a number of the very time-consuming, and sometimes difficult, duties of merely dispensing knowledge, and allow him more time to work individually with trainees in resolution of their specific learning problems.

The physical actions required of the trainee during instruction on this device can readily be inferred from the above discussion. He would take a variety of actual test readings, would feel and hear many of the same cues provided by a real engine, and make a number of actual calibrations and adjustments. He would also be able to complete a number of troubleshooting procedural sequences beginning with initial analysis of a trouble symptom, identification of the malfunction, prescription of the proper corrective procedure, and execution of the corrective action. This last step, in some cases, would involve physical manipulation of parts of the engine mock-up, while in other cases the action would be simulated through pressing appropriate repair or remove/replace buttons on the FPSS.

Capabilities for measurement of trainee performance and provision of feedback to trainees, based on current technology, could be built into this device and provide many advantages over the AET. AETs have no performance measurement features such as visual or printed indications of correct responses or errors, provision of error messages or confirmation of correct action decisions, or measurement of the time a trainee consumes in completing those actions or decision processes. Immediate knowledge of results and printed records of trainee achievement would be features of this device which would enhance both the trainees' movement through the course and the measurement, grading, and record-keeping activities of the instructors.

When compared to an AET, the support requirements for this device would be minimal and would offer great savings in space and other resource requirements. The device would require a small amount of floor space and only a 110-volt AC power supply. There would be none of the fuel supply or exhaust emission requirements associated with AETs, thus reducing both energy usage and air pollution to a fraction of current levels. In addition, high-noise areas created by the location of large numbers of actual engines in an enclosed shop would not exist, thus eliminating another potential health hazard. A clean, air-conditioned environment would enhance the operation of the device, and this would perhaps be the most stringent support requirement.

This device would be best suited for use in institutional training where the inexperienced trainee might need the visual system configuration and logic displayed by the FPSS. The device would assist in teaching the trainee how the system functions, what it does, and what actions he is to take. With that knowledge basis, he can be more easily taught how to take the appropriate maintenance actions in later segments of AIT or in OJT.

Device 2. The basic configuration of this proposed device (see Figure 2.) would be a generic engine block. This block would be under microprocessor control and would incorporate an electric motor to simulate various normal or abnormal running conditions as described for Device 1.

At appropriate locations throughout the engine block, electrical plug-in points would be provided. At these points, replicas of the various fuel and electrical system components, containing internal electronic circuitry, would be plugged into the engine bloc and come under control of the microprocessor. For a gasoline engine, for example, these replicas, or electronic modules, would include such components as the starter, generator, fuel pump, water pump, carburetor, distributor, coil, and spark plugs and wires.

The generic engine block, therefore, would form the foundation for a family of engine troubleshooting devices. With the block as a core, replicas of components of various engine types (gasoline, diesel or multifuel) and applications (automobile, trucks, heavy equipment) would be manufactured. With these modules attached to the core block, the generic device would become a realistic representation of a specific engine. By interchanging modules for different engine types, one block could provide instruction on a variety of engines and eliminate the requirement for a specific AET for each type of engine studied.

As in the Device 1 concept, instruction provided by this device would involve both diagnostic and hands-on tasks. The hands-on tasks that could be taught would include, for example, the capability to remove spark plugs and perform a compression test on the cylinders. The opening from which the spark plug was removed would contain an electrical contact and the reading on the compression gauge would be triggered electrically, but the procedure would be the same as performed on an actual engine. Other examples would be the approximate setting of the engine timing by positioning the distributor, and the precision timing of the engine using a timing light. In addition, actual contact points could be provided in the replica of the distributor to allow practice of the procedure for setting the point gap.

Use of this device would also modify the instructor's role in the same manner as described in the Device 1 concept discussion. To avoid repetition of detail, the reader is referred to that discussion for this information as well as that referred to periodically in following paragraphs.

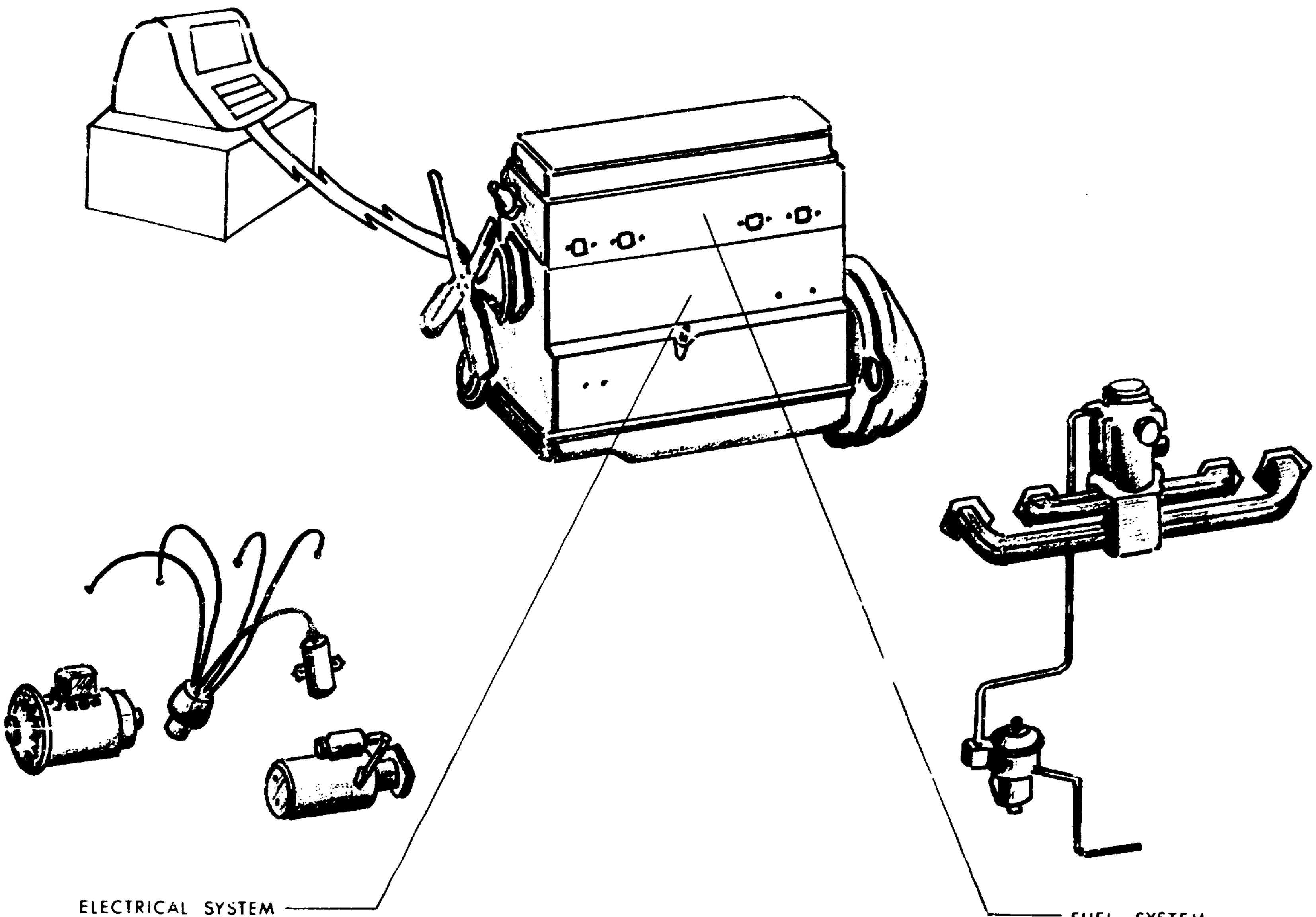

Figure 2. Engine Troubleshooting Device 2.

The trainee interaction with this device again can be inferred from the preceding discussion. Since this device will not incorporate an FPSS as did Device 1, engine system diagrams and visual displays would not be present. The trainee would, therefore, interact more directly with the engine mock-up in performing diagnostic procedures and completing motor tasks such as adjusting the fuel mixture and setting the point gap. The same performance measurement and feedback capabilities as described in Device 1 could be incorporated into this device.

The device's support requirements in terms of floor space would be approximately the same as an AET, but requirements for physical resources, especially energy, would be minimal as compared to AETs. One significant support requirement, however, would be the development of replicas of test equipment that would provide such readings as, for example, cylinder compression (in pounds per square inch), but would utilize an electrical source.

As stated earlier, the organizational mechanic can face a bewildering array of vehicle types upon reporting to his unit assignment. Moreover, his institutional training more than likely was focused on a relatively small number of vehicles, and the transfer of that knowledge to other systems is expected to occur through OJT. Because of the flexibility offered by the core engine block and interchangable module concept described here, this device is recommended for use at the unit level so that training of new maintenance personnel, or retraining of experienced personnel, can be offered on a device configured like the equipment used in that unit. This could significantly reduce the amount of time the unit's crucial equipment is diverted from operational missions for use in OJT.

Troubleshooting Track Vehicle Track/Suspension Systems at the Organizational Level

In the training of track vehicle and automotive mechanics observed in this study, this skill is taught using an entire tracked vehicle as the training device. It is difficult to "bug" equipment as cumbersome as the track/suspension system on one of these vehicles, so much of the instruction on this task can be offered only when an operational vehicle is available that exhibits a set of malfunctions that can be diagnosed and corrected. Another option present in training is to use an AET that exhibits a specific set of problems which are merely diagnosed by the trainee and not corrected. The next group of trainees is required to diagnose the same set of problems, resulting in a situation where trainees sometimes know a priori which set of responses will result in a "go" on that segment of instruction. Furthermore, the number of malfunctions that can be introduced into training is severely limited.

A device concept proposed for teaching this skill, therefore, is a microprocessor-controlled mock-up of the track/suspension system of a tracked vehicle including the suspension arms, road wheels, and tracks. This device, illustrated in Figure 3, would be mounted on a platform. Powered by an electric motor, rollers or continuous belts would drive the tracks to simulate both horizontal and vertical motion of the suspension system as if the vehicle were moving over terrain.

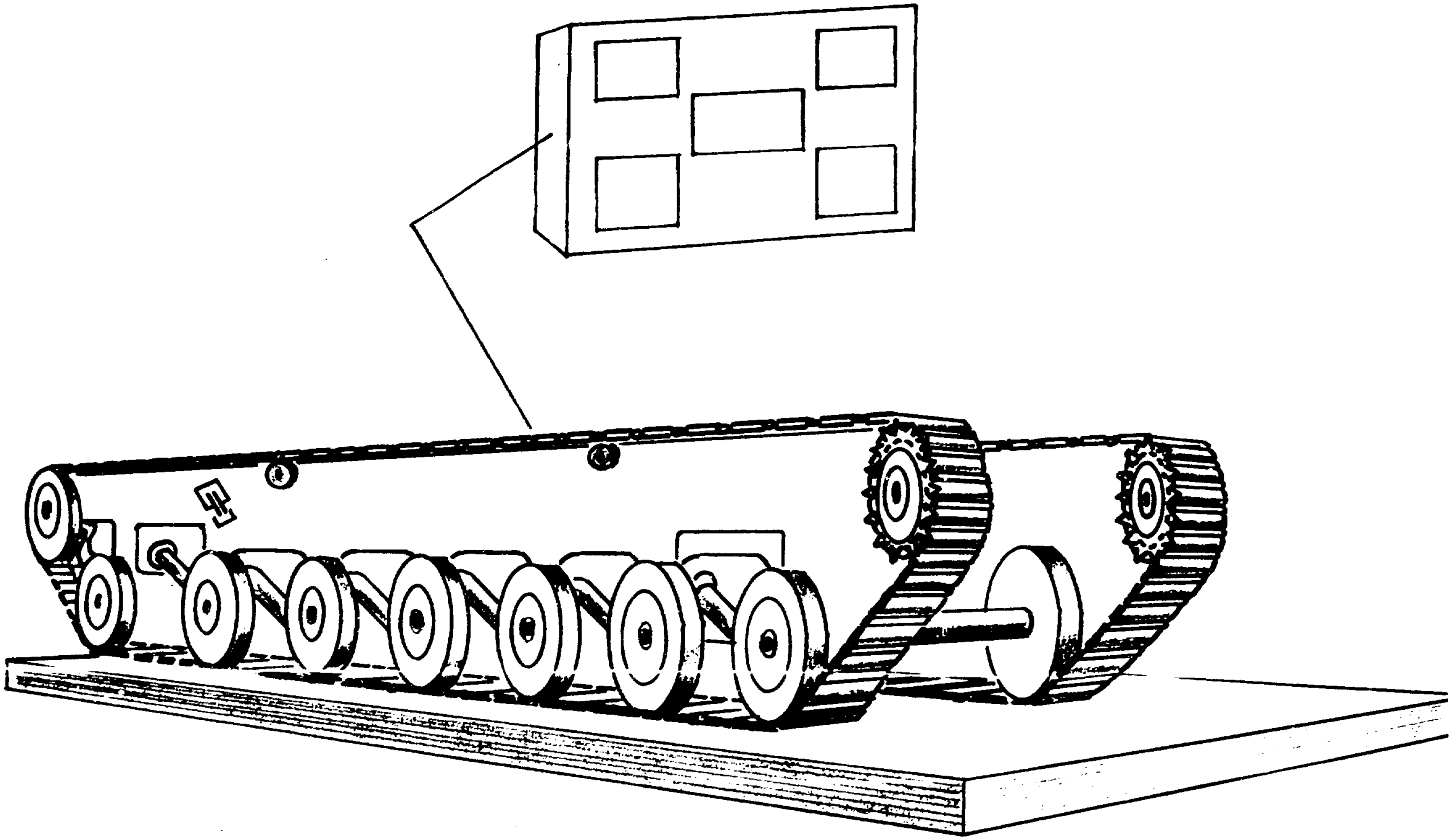

Figure 3. Track/Suspension System Troubleshooting Device

The instructional capabilities of this device would allow the trainee to observe, diagnose, and correct a number of malfunctions such as rough riding, pulling to the left or right, sagging to one side, or alignment problems. The trainee would correct these types of symptoms by pressing a repair or remove/replace button located on the component or on a control panel. Simulation of such malfunctions as leaks in cylinders or idler wheel hubs would be accomplished by the computer activating a "leak" light at the appropriate point on the mechanism. The trainee would then show his repair of the leak by pressing a button indicating the correct action.

In presenting other types of problems such as a track that has slipped off a road wheel, the trainee would use replicas of actual tools, such as a pry bar, in correcting the problem. The track would be made of a material that would be lighter than an actual track, so wooden or ruggedized plastic replicas of actual tools could be used. The trainee, however, would be exposed to all aspects of the repair procedure except the weight of the objects involved. Thus, he would know precisely what to do when he is first confronted with that particular problem on an item of actual equipment.

As in previously described troubleshooting device concepts, use of this device would cause the instructor to become more of a guide of learning than a dispenser of knowledge. In addition, the performance measurement and feedback capabilities of this device would be similar to those already described.

Since this would be a full-size mock-up of a track/suspension system, the floor space requirements for this device would be the same as for an AET. Other requirements would include appropriate tools and access to an electrical power supply.

Because the track/suspension systems of most tracked vehicles contain many similar components, it is recommended that a generic device be built representing a class of vehicles (i.e., tanks or the new infantry fighting vehicles). Thus, this device would be best suited for the introductory training presented in AIT.

<u>Removal/Replacement of Engines and Power Packs at the DS/GS Level</u>

In the training observed during this study, the removal and replacement of wheeled vehicle and tank engines and power packs was a skill taught without exception using an entire vehicle as the training device. This skill could be taught more cost effectively using a mock-up of the engine/power pack (power plant) portion of the vehicle rather than dedicating an entire vehicle to the task.

The device concept suggested for teaching this skill, therefore, is a mock-up of the power plant compartment of a tank or a truck, incorporating a replica of the power plant. Figures 4 and 5 illustrate this concept. The power plant replica would be a hollow metal shell, shaped and weighted like an actual power plant. It would provide the actual hands-on experiences and would incorporate all the attachments and accessories of the actual power plant, allowing for use of real tools and hoist equipment in the instruction of this task.

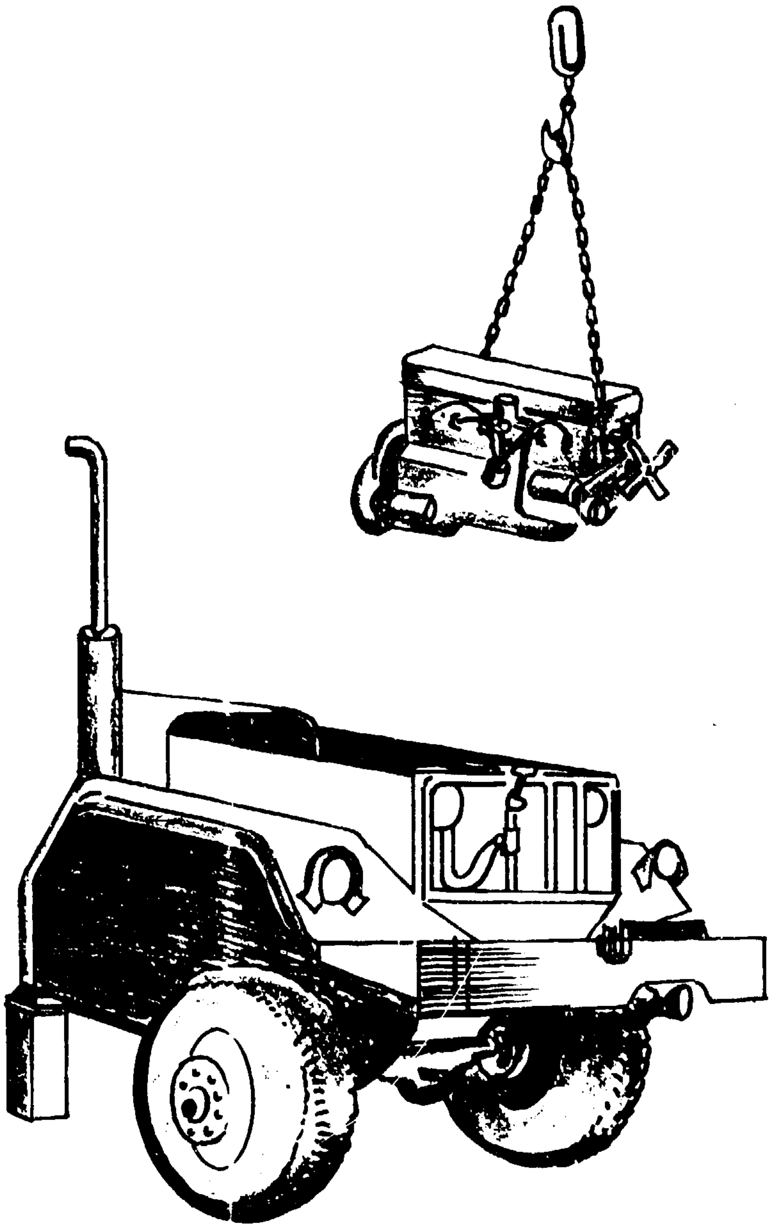

Figure 4. Truck Engine Removal/Replacement Device

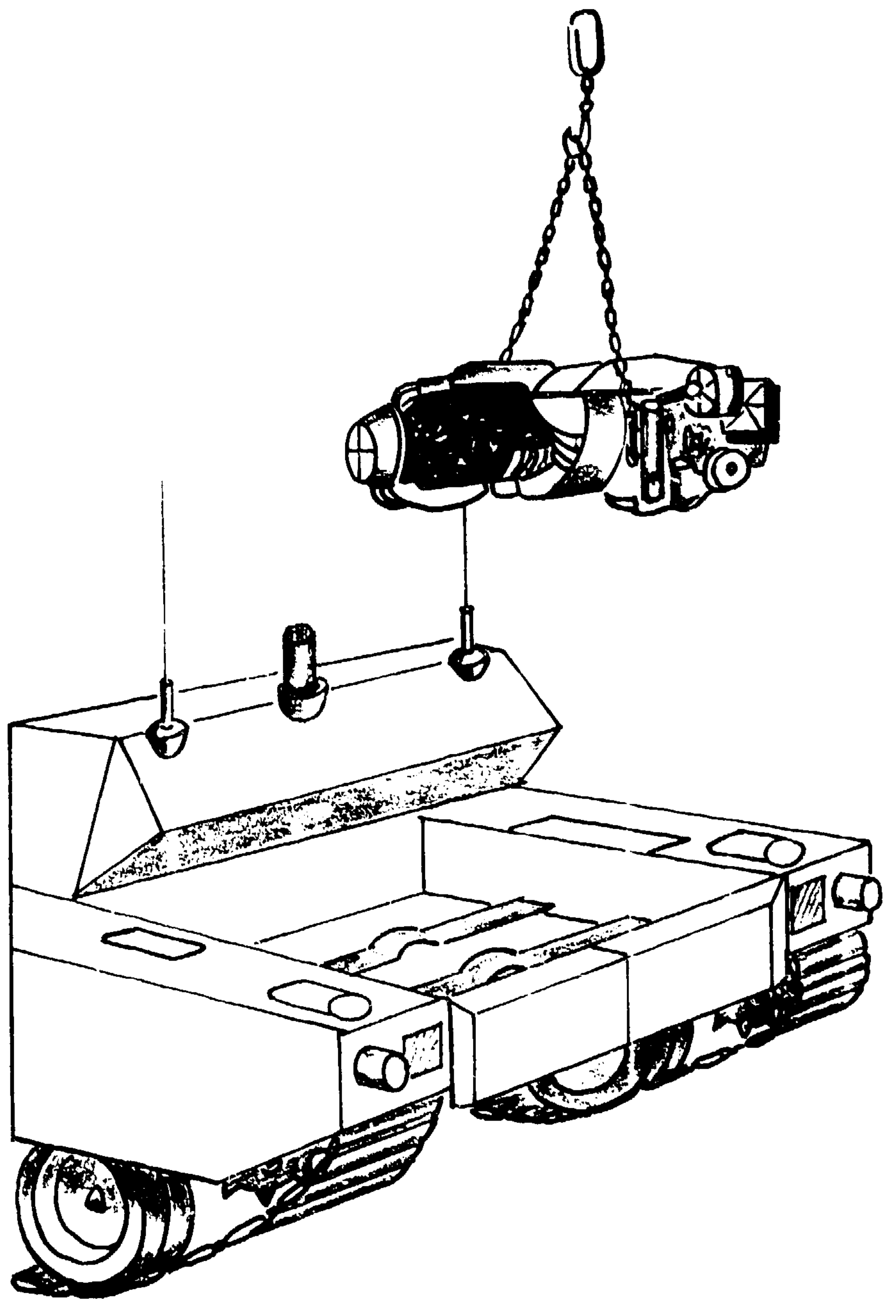

Figure 5. Tank Power Pack Removal/Replacement Device

This relatively straightforward motor task is outlined in detail in the TM for the particular vehicle, and trainees are required to complete the sequential procedures as described. The sequence in which the accessories are unhooked or removed, the manner in which the sling is placed around the engine, and the precautions taken in lifting the power plant from the compartment are described fully in the TM. Since the trainees perform this task "by the numbers" from the TM, the instructor's role in teaching this task is minimal and would not change if this device were used. The trainee, also, would interact with the device in exactly the same manner as with the AET.

Because this task comprises a series of straightforward motor tasks, no particular performance measurement or feedback capabilities are required of the proposed device. Since the device is a mock-up of only a portion of the AET, it would require a smaller working space, and, with the exception of the hoist apparatus needed, would consume no energy resources.

A generic device representing tank power pack compartments and another representing truck engine compartments could provide an appropriate introductory level of training for this basic maintenance task. The proposed device, therefore, would be best suited for use in institutional training.

Troubleshooting Turret Electrical and Hydraulic Systems at both Organizational and DS/GS Levels

As described in an earlier section of this report, the difficulties encountered by a trainee in performing troubleshooting tasks are compounded by the complex nature of the many turret systems which incorporate both electrical and hydraulic components. In addition, the high cost of turrets and their general ineffectiveness as training devices, due primarily to lack of working space and visibility problems, have also been cited.

Four turret training devices, all designed around a single device concept but possessing different physical characteristics, are described in the following paragraphs. In this discussion, the generic device concept (pictured in Figure 6) is presented, followed by physical descriptions of the four alternative devices. The instructional capabilities and related functions of the devices are then discussed.

The basic device concept around which each of the four alternatives is developed is that of a mock-up turret incorporating a flat-panel system simulator within the structure. The electrical and hydraulic components and and circuitry of the various turret systems, color-coded for easier differentiation by the trainee, would be represented in their appropriate locations. Each device would house functional representations of such components as the commander's panel and gunner's control switches.

To maximize each device's instructional capabilities, the physical structure must be designed to overcome the space and visibility weaknesses of the turret AET. The basic difference among the four devices described below is the manner in which the visibility problem is overcome. The first alternative utilizes an open skeleton framework, while the latter three devices incorporate transparent side panels which would fit into the

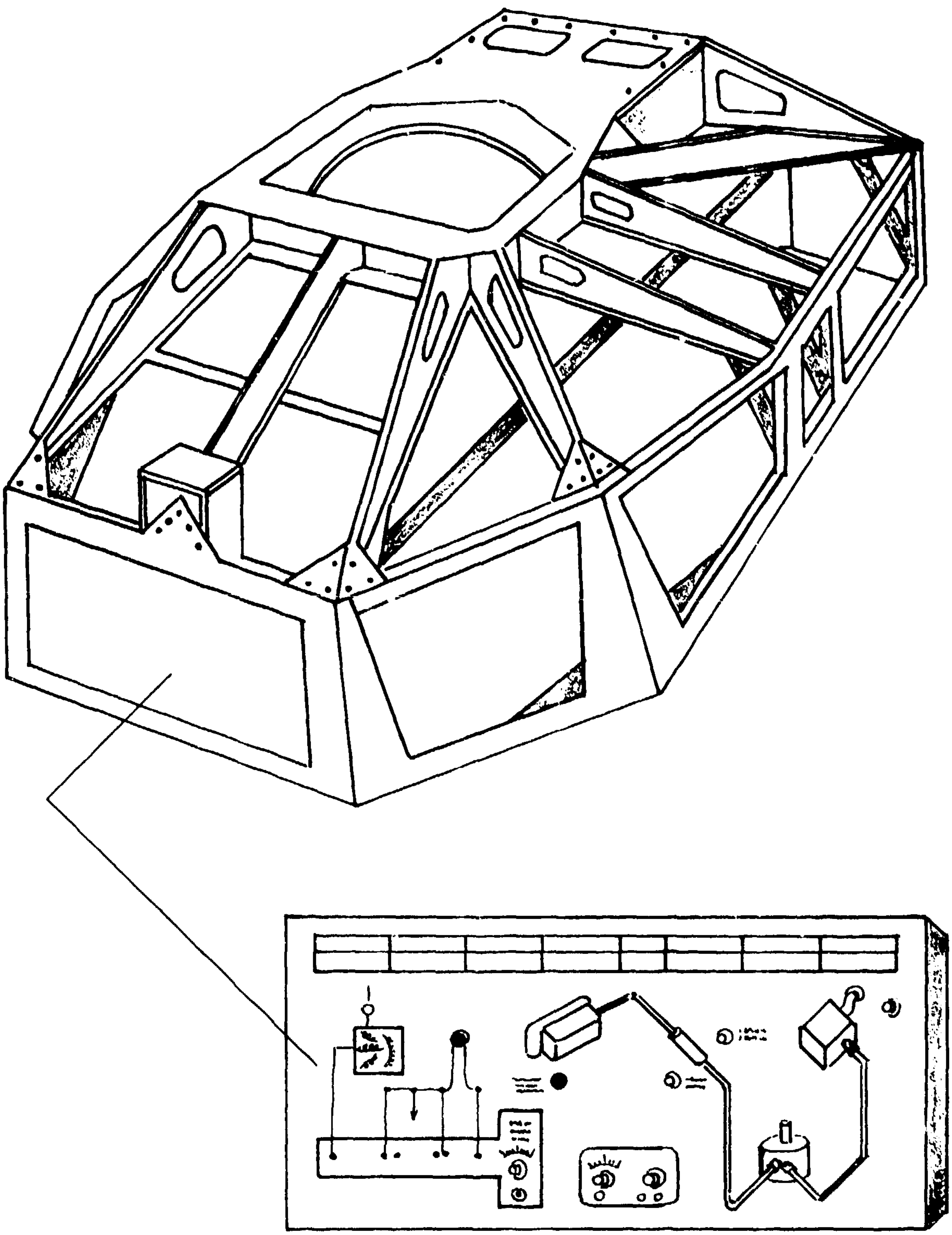

Figure 6. Turret Electrical and Hydraulic System Troubleshooting Device

skeleton framework. In this manner, the internal systems and components of the turret would be visible from both inside and outside the structure, allowing for maximum flexibility in individual, small-group, or large-group instruction.

To alleviate the problem of lack of working space, it is recommended that all four mock-ups be built larger than actual size. In self-paced instruction, space must be provided for the instructor and trainee(s) to work together and have access to tools, test equipment, and TMs. Space within a turret AET for that type of interaction is severely limited, and larger-than-scale construction of the training devices would greatly enhance the instructional process.

The FPSS incorporated within each device is an extremely important feature. Due to the complexities of turret systems, particularly the electrical systems, clearly presented functional diagrams of the systems and their flow and logic are necessities in turret troubleshooting training. In fact, this was the only area of maintenance training observed in this study where the instructors were eager to discuss RPF alternatives to AETs. Recognizing the interaction between the intellectual ability levels among trainees and the sophistication of modern turret systems, those instructors cited their need for device alternative to AETs that would facilitate instruction of turret troubleshooting.

The instructional features of the FPSS for turret troubleshooting would be similar to those described in earlier troubleshooting discussions. This would include the display of system diagrams, provisions of buttons to indicate the test, repair, or removal/replacement of a component, and provision of error messages or confirmation of correct responses. Dials and gauges would also be displayed as needed. The FPSS would also contain an instructor's control panel for selection of malfunctions and for making the various trainee performance measurements cited earlier.

Based on this general description, additional detail on each of the four alternative devices is presented below.

Alternative 1. This device would consist of a skeleton frame forming the shape of a turret. Attached to the open framework in their actual locations, would be mock representations of the circuitry and components of the various systems. The trainee would do work in the turret while being observed and assisted by the instructor from either inside or outside the open framework.

The system components in this version of the device would be functional in that the trainee would use his LVCT and multimeter in performing various tests. Removal/replacement of a component could be indicated by pressing a button on the FPSS panel or by actual manipulation of the components, if they could be made of ruggedized, long-lasting material.

Alternative 2. This version of the turret would contain interchangeable transparent side panels which would fit into the skeleton framework. Laminated within the panels would be visual color-coded representations of the components and circuitry of the systems, and the device would include a different set of panels for each system being studied. To provide instruction regarding a particular system, the instructor would place the transparent side panels in the turret skeleton in initial phases of training, but could put multiple sets of panels in place in later phases of training so the trainee could do work associated with several systems at the same time. The side panels in this option would be inert, and the trainee would do all the troubleshooting work on the FPSS. This would require a simulated LVCT and multimeter be built into the FPSS.

Alternative 3. This would be essentially the same as Alternative 2 except the interchangeable transparent side panels would also be interactive. Wiring would be incorporated within the panels so the components could be controlled by the computer and the trainee could make tests with the meters at the actual locations. Since the panels would contain live test points, the actual LVCT and multimeter could be used, thus allowing for their removal from the FPSS in this version of the device.

The engineering required to provide interactive panels that could be removed and replaced, however, would be extensive. Contact points and wiring would need to be incorporated within both the panels and the main structure, increasing their physical complexity.

Alternative 4. In this version the transparent side panels would not be interchangeable, but would be interactive. Rather than a set of panels for each system, in this version all the systems would be shown in color coded representations within fixed transparent side panels. The components of the systems represented within the panels would be wired so they would be under control of the computer and live test points could be located in the same positions as in the actual turret. Since the panels in this version would be fixed in place within the skeleton framework, their engineering would be less complex than in Alternative 3.

The instructional capabilities of all four turrets would be essentially the same, and the four are designed to accomplish many common troubleshooting tasks. Through the FPSS control panel, the instructor would select a malfunction in, for example, the electrical system. The trainee would attach either his LVCT or multimeter at appropriate points in the circuits, determine the reading and interpret its significance. (An exception to this would be present in Alternative 2, whose side panels would be inert, and the LVCT and multimeter readings would appear on the FPSS panel). If removal and replacement of a component is indicated, the trainee would press the appropriate remove/replace button on the FPSS, which would either confirm his correct decision or present an error message. If the decision/action was correct, the instructor would select another malfunction. If the trainee was in error, he would attempt to rectify it. Throughout this procedure, the FPSS would be recording the trainee's actions and measuring the time required in their performance.

Again, as described in earlier troubleshooting sections, the instructor's traditional role would be modified if this device were used in troubleshooting training. The trainee's interaction with this device would be much the same as cited in other troubleshooting discussions, except that he would be surrounded by a three-dimensional representation of the actual turret.

Since these devices would be larger than an actual turret, some additional floor space would be required. An electrical power source would also be a necessity.

These devices could be used in both institutional and unit training. They would provide excellent introductory training in AIT, and could be quite useful in skill improvement training at the unit level.

Regardless of which configuration of this device would be used, the ability of the instructor to work with the trainee from inside or outside the turret, the turret being larger than actual size for easier access, and the addition of a systems simulator would enable the device to provide training in a wider range of malfunctions and problem situations in a more cost- and training-effective manner than existing turret AETs. These features could have a positive impact on the training of turret mechanics in both institutional and unit settings.

EVALUATION OF TRAINING EFFECTIVENESS

The purpose of Task 5 was to develop a methodology for evaluating the relative training effectiveness of the various RPF devices identified in Tasks 3 and 4. The methodology is to provide for a comparison of the training effectiveness of each device with a corresponding AET, and with an alternative device when available. When implemented, the methodology will produce data which can be used not only to assess the effectiveness of each device for achieving training objectives, but more importantly, their effectiveness in preparing trainees to perform on the job. In addition to serving these purposes, the data will provide needed input for analyses of training cost effectiveness.

The present section presents an overview of the evaluation methodology that was developed during Task 5. It provides (1) an instructional context for the evaluations; (2) a discussion of the pertinent facets of the context as they apply to the present development of an evaluation methodology; and (3) a description of the technical capabilities that must be represented among personnel conducting the evaluations.

Appendix D presents the evaluation methodology in substantial detail. That Appendix is intended for use as a guide in the eventual implementation of the evaluations. As a guide, it develops a framework for conducting the evaluations that, with suitable adaptations, can be applied to each of the devices as it is used in each of the various target training programs.

Instructional Context for the Evaluation

The evaluation of a training device can be viewed within the context of training course development. Various branches of the military have jointly developed a set of procedures, commonly referred to as ISD [1/] which includes

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[1/] Interservice Procedures for Instructional Systems Development. TRADOC Pamphlet 350-30, Headquarters, U.S. Army Training and Doctrine Command, Ft. Monroe, Va., 1 August, 1975.

seven major steps to be followed in conceiving, developing, implementing, and evaluating a training course. These steps will not be detailed here. Instead, eight related or derivative procedural steps of particular concern in training course evaluations will be identified. Five of these steps will be discussed at some length in the section that follows, and then treated in considerable detail in Appendix D.

The eight procedural steps for evaluation are as follows:

1. Statement of the evaluation problem. The evaluation problem as it applies to the particular case at hand must state clearly the issues to be resolved, and in such a manner that requirements for the remaining procedural considerations are clearly determined.

2. Analysis of cognitive and manipulative skills to be taught. Specific training objectives for the course of concern must be stated in terms of those knowledges and skills required for job performance, and for which trainees are to be prepared in the course.

3. Development of the training course. This step encompasses the design of the instructional process whereby course objectives are to be achieved.

4. Selection of criterion measures. Psychometrically sound measuring instruments and procedures must be available for determining as objectively as possible the extent to which course objectives are achieved by trainees.

5. Design of the evaluation. All independent variables of concern in the evaluation must be identified and their roles must be implemented in such a way that the data to be collected reflect clearly the effects of each such variable. In addition, provisions must be made for controlling the effects of variables that are not in themselves of concern, but which, if not controlled, can prevent a clear identification of effects of the independent variables.

6. Collection of data. This step must provide for the administration of all measuring instruments. The sources of data must be specified and a schedule for the collection established.

7. Analysis of data. The conceptual structure for examining data should be clear at the outset, and a basic analytic schema established.

8. Integration of findings vis-à-vis the evaluation problem. The procedures involved in this step are to be directed toward resolving issues which gave rise to the evaluation effort, using the information obtained from that effort.

Procedural Considerations Applicable to the Present Effort

Three of the procedural steps above go beyond the scope of the present effort. Specifically, Steps 2, 3, and 8 will be part of the final evaluation effort, and the previously referenced ISD procedures provide adequate guides for their completion. Hence, they will not be discussed further in this report except for general considerations concerning them as they apply to the remaining steps.

Steps 1 and 4-7, or certain aspects of them, are of particular concern in this project. They, too, are included in ISD procedures, but Task 5 of this project calls for adapting these steps to the unique problems of evaluating the maintenance training devices identified in this report. The remaining part of this subsection will discuss these five steps in order, focusing upon their adaptations to the evaluation of maintenance training devices.

Statement of the problem. This step has two facets. The first is to provide a guide for deriving the remaining procedural steps; and, second, by its derivation, it should provide a framework for interpreting evaluative data and for determining adaptive actions based on the data. The second facet is covered in Section I in discussions of the need for better, cost-effective maintenance training, the military problem of providing such training, and the research problem prompted by the need and the military's reaction to it.

The first facet of the problem statement is a clear definition of the issues to be resolved, stated so as to establish requirements for the remaining procedural steps. For present purposes, the problem is to determine the training effectiveness of certain alternative maintenance training devices relative to corresponding AETs, and, in some cases, to alternative devices. The problem requires that research procedures be established for answering, or otherwise resolving, seven questions regarding training. These questions are:

1. What kinds of measures can be used that are indicative of training effectiveness?

2. From what sources, under what conditions, and when should these measures be obtained?

3. How are the measures to be analyzed so as to provide comparative indices of RPF and AET training effectiveness?

4. Is the effectiveness of a device, including AET, dependent upon certain instructional modes?

5. Is the effectivness of a device per se, or its use in alternative instructional modes, dependent upon certain student characteristics such as aptitude level or amount of relevant experience?

6. Because instructors may vary in the effectiveness with which they use various devices in training, how are instructor effects to be provided for in the analyses?

7. Because training sites may differ in ways affecting device use and training value, how are the effects of these differences to be determined or otherwise provided for in the analyses?

The subsections which follow address these questions generally through discussions of the remaining procedural steps identified earlier. For detailed discussions of the issues involved, see Appendix D.

Selection of criterion measures. The primary concern in evaluating training devices is the adequacy of on-the-job performance of graduates of training programs using the devices. It is necessary therefore that job competence of graduates be assessed, and in a manner that reveals the adequacies, and lacks thereof, of devices used in preparing them for unit responsibilities. Adequacy of job performance is only partially determined by the fulfillment of AIT objectives, i.e., the achievement of cognitive and hands-on skills per se. Such skills are necessary, but they must be integrated into appropriate judgments and actions as determined by the cues and demands of real-world situations. In addition, the graduate trainee is expected to progress on the job beyond the achievement levels attained in AIT. Hence, indicators of job performance must tap capabilities and actions that cannot be observed during AIT.

Time constraints require that such assessments be made soon after prototype training devices become available, for decisions regarding the procurement of additional devices must be made without undue delay. Hence, job performance measures that are revealing of competence, and that can be obtained relatively soon after training, must be used.

A second set of measures, a group administered during and immediately upon completion of AIT, should include knowledge or cognitive skills, and manipulative or hands-on skills. Such measures can reveal specific strengths and weaknesses of training programs according to attainments of particular training objectives. These indicators would not only reveal trainee achievement during training as it relates to device use, but to the extent that such achievement is predictive of later job performance, they provide data within the time constraint that can be used in decisions regarding device procurement.

To be useful for evaluating training devices, measures obtained on the job, or during or at the end of AIT, should focus upon aspects of achievement which are relevant to device design and utilization. The devices to be evaluated will be used for only certain segments (e.g., gasoline engine maintenance) of overall AIT training. Furthermore, among the training objectives concerned with these particular segments, the achievement of only certain ones can reasonably be expected to be enhanced by given devices. Device-relevant objectives should be identified, and provisions should be made for separating measures of their attainment from measures concerned with objectives not related to the purposes implied by device design and use.

A different type of measure, one of user acceptance of the various devices, will also be needed for device evaluation. The focus for such measures should be upon the satisfaction of trainees and instructors with training devices used, and upon job supervisors' satisfaction with trainees after training. Because the value of a device depends to a great extent upon how it is used, acceptance measures should reflect satisfaction with the relevant segments of the training program as well.

Device acceptance by trainees, instructors, and by implication, supervisors, is of concern for two reasons. First, it is important, although perhaps not crucial, for morale that users of given programs and media see them as valuable, and their roles in them as satisfying. Second, in the event that a device is or could be training effective, but generally is not seen as satisfactory by groups of users, establishing its nonacceptability would provide a signal for possible device design changes or for needed managerial actions directed toward educating the users regarding the device's value.

Still another kind of measure that can aid in the evaluation of a device concerns characteristics and utilization of the device itself. Information sought by these measures includes amount and nature of device use; instructors' and trainees' critiques of the device; the level, depth, and comprehensiveness of training attempted with the devices; adequacy of software; amount and nature of instructor and trainee effort required to use the device; equipment set-up time; etc.

Design of the evaluation. The training device is the independent variable of primary concern. Hence, the focus for the evaluation is on the comparisons of the training effectiveness of various RPF devices with corresponding AETs, and when they are available, the comparisons of alternative RPF devices. Important to these comparisons are the effects of using the devices (including AETs) in lock-step as opposed to self-paced programs. In addition, the effectiveness of each device for trainees of different aptitude levels or amounts of relevant experience is of concern. Hence, data should be collected that permit meaningful comparisons of device effectiveness separately by instructional mode, and by these trainee characteristics.

These comparisons require that separate training groups be established for each device-instructional mode combination. Within each group, all levels of trainee characteristics are to be represented. Furthermore, possible confounding influences on achievement due to differential instructor effectiveness should be avoided as described in Appendix D.

It is especially important that training programs using a given device be standardized, so that achievement and other data relevant to each device are comparable. The only variations from strict training program standardization that can be permitted are those necessary for providing lock-step vs. self-paced instruction, and those necessary due to differences in device instructional capabilities. In either case, however, the program for a given instructional mode or device should be standard.

Even so, evaluation data are to be gathered from different training sites, and even though program standardization is attained, local training philosophies and other similar influences can render data noncomparable. The evaluation design must provide for this eventuality.

Collection of data. Achievement data should be collected on each trainee at the end of AIT, and during AIT as relevant data are available. After approximately two months of unit assignment following AIT, job performance data for each trainee should be obtained from job supervisors and otherwise as discussed in Appendix D. In addition, trainee performance on the Skill Qualification Test, normally taken six months after unit assignment will provide additional data regarding knowledge and skill levels, and some aspects of job performance.

User acceptance data should be obtained from trainees immediately following AIT, and again from them and from job supervisors approximately two months following unit assignment. Similar data should be obtained from instructors at the end of the AIT course used in the evaluations. Also at that time, the information discussed above regarding characteristics and utilization of training devices could be obtained from the instructors.

Analysis of data. Most criterion data can be analyzed using a basic three-factor analysis of variance (ANOVA) with type of device, instructional mode, and one type of student characteristic comprising the three factors. When additional data for other factors are available, such as a second type of student characteristic or location of training program, they should be added to the basic ANOVA.

Another kind of adaptation to the basic ANOVA will be necessary in some comparisons when complete sets of data are not available for all of the three basic factors. In such cases, the incomplete factors would simply be dropped from the analysis.

A few data will be in categorical form and hence not in a metric suitable for ANOVA. Chi square, or some other nonparametric statistical analysis as indicated, would then be used. The structure of the analyses should conform to the factor structure of the basic ANOVA, although no more than two of these factors would be involved in a single analysis. Repeated analyses of the same data with various factor combinations would then be necessary to provide a complete picture of the results.

Support Personnel

Seven types of technical capabilities must be represented on the team that conducts the training evaluations. These capabilities are:

1. Expertise in administering training program evaluations;

2. Expertise in job/task analyses and in deriving training requirements from them;

3. Expertise in training course design, with special emphasis on training device utilization;

4. Expertise in developing measuring instruments;

5. Expertise in experimental design, especially the adaptation of design requirements to varying local training conditions;

6. Expertise in data analysis in general, and in ANOVA and chi square analyses in particular; and

7. Technical expertise in subject matter.

IV. DISCUSSION

Army maintenance training is undergoing changes that parallel many of those occurring in other types f Army training. Many of these changes are quite fundamental in nature, especially those relating to the use of devices to support that training. Some of these changes--e.g., the shift toward performance-based, individualized instructional programs--have been discussed in this report, as have their implications for the training device concepts developed. Clearly, the emphasis on reducing training costs wherever possible is going to continue, but this cannot be done at the expense of the resultant maintenance skills. In fact, the need is for a training system that can produce mechanics with both increased breadth and depth of skills. Thus, the demands being placed on the Army maintenance training system are increasingly severe.

Over and above these continuing considerations, there is the even more critical requirement that operational units be combat ready. In this regard, the undesirability of diverting operational vehicles and equipment from their intended mission use to institutional and unit training programs has been discussed. Another consideration related to combat readiness is the assumption that future conflicts will not allow the luxury of a lengthy period in which the unit can build its operational capabilities through OJT. [1/] Units must be ready to perform operationally without delay.

The problems that this state of affairs presents for maintenance training are complex. The inventory of vehicles and equipment the mechanic must be prepared to maintain is extensive, but the capability of present institutional and unit maintenance training programs and equipment to provide such preparation is limited. While there are many reasons for these training program limitations, the one of major concern here is the heavy reliance on the use of actual equipment to support training, i.e., the use of AETs. Aside from their sometimes substantial cost and their generally poor suitability for instructional use, AETs present a further difficulty in that the Army cannot realistically expect to provide them for all of its vehicles and equipment, nor can it expect to expose each trainee to all AETs that do exist. Thus, other solutions warrant examination.

In the present effort, the potential of RPF devices to meet many of the maintenance training needs presently being met through use of AETs has been examined, and several such device concepts have been described. The RPF concepts described treat four high-priority training areas, areas involving both substantial numbers of trainees and numbers of costly AET devices. Because of these factors, the RPF concepts presented offer a potential for substantial future cost savings. In addition, they offer the potential for more effective training in certain skills presently trained inadequately or not at all with existing AET devices and for training for a much broader

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[1/] This assumption has lead some to characterize any possible future conflict as a "come-as-you-are war." Perhaps less colorfully, this assumption is reflected in the emphasis in current Army doctrine on "winning the first battle."

spectrum of current inventory vehicles. It is this extended training potential that will ultimately impact most heavily on future Army unit readiness.

In terms of training device technology, the RPF concepts described offer the potential for development of multipurpose families of devices to support maintenance training of broad scope. The concepts could be adaptable to either institutional or unit training and, thus, provide a means of enhancing Army maintenance training at all levels. The mechanic who has been trained on a particular subset of vehicles or systems and is then expected to effectively maintain a vehicle subset that may be quite different faces a considerable problem. Hence, the flexibility the multipurpose device presents should be attractive to the unit commander as well as to the institutional training manager.

Obviously, the potential benefits described will be realized only if the device concepts are carried through to prototype development and then subjected to evaluation as to their training effectiveness and possible cost benefits. This report describes the major features of such evaluation. It should be noted, though, that the training effectiveness evaluation of the various device concepts need not cover every possible implementation of the concept, i.e., its extension to every potential system or vehicle. Concept feasibility can be evaluated on a more restricted scale. If results are favorable, then the extensions can be made, where deemed appropriate by the Army, on production devices.

In pursuing the development and evaluation of prototype RPF devices of the types described, special attention must be paid to the task-analytic basis from which they would be developed. As is noted elsewhere in this report, the task listings and task analyses on which the various current school training courses have been built are of variable nature. It is doubtful that any of the existing task lists or analyses is sufficient for the development of detailed performance specifications for the RPF devices. Therefore, if the Army pursues any of the RPF device concepts described here to the prototype development stage, a first necessary step would be the conduct of a thorough task analysis for the training of concern in order that the characteristics of the resultant device would best relate to the critical skill and training requirements. To omit this step would almost surely lead to devices that were not optimal for the actual training requirements of concern. This step is, of course, a highly important step in the development of any training device, whatever its level of complexity. However, when device physical fidelity is being reduced deliberately, as in the RPF device, particular care must be given to insure that critical task/psychological aspects of training fidelity are not inadvertently reduced.

The Army has made great progress in the use of complex simulation devices to support operator training in aviation, and it has similar programs in development for tank crew training. Maintenance training devices have received much less attention, but the current Army program to develop such devices, of which the present effort is a part, reflects an increased overall recognition of the importance of and interest in maintenance training in the Army. The large numbers of hardware systems and trainees involved in maintenance training dictate that training device approaches such as the RPF play an important part in that regard. The RPF will not be the only device approach of importance in future Army maintenance training--complex devices and AETs will have an interfacing role--but the potential it represents appears considerable and warrants its thorough investigation and evaluation by the Army.

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APPENDIX A

ARMY MAINTENANCE TRAINING

This appendix presents information developed in the Task 1 survey pertinent to Army training courses in the automotive, track vehicle, and heavy equipment maintenance areas. The first part of the appendix is a discussion of the manner in which the 24 major areas or domains of maintenance training were developed for use in Task 2. Four of the 24 areas were then selected for the development of RPF concepts in Tasks 3 and 4. For further discussion of the four areas selected, see Section III of the basic report and Appendix C.

The second part of this appendix presents selected descriptive information covering the 12 MOS-producing courses covered in the Task 1 Army training survey.

MAINTENANCE TRAINING CATEGORIES

MOS and Training Category

The study was initially designed to focus separately on the areas of automotive, track vehicle, and heavy equipment maintenance training. Data developed during the Task 1 survey, however, indicated the desirability of combining certain aspects of training in these areas. For example, automotive repairmen (MOSs 63H10 and 63H20) and heavy equipment mechanics (MOSs 62B10 and 62B20) receive training in maintenance of both wheeled and tracked vehicles. Furthermore, the track vehicle mechanics (MOS 63C10) also receive training on wheeled vehicles. In contrast, turret mechanics and repairmen (MOSs 45K10, 45K20, 45N10, 45P10, and 45R10) are confronted with problems and systems unique to turrets and with maintenance tasks somewhat different from those experienced by repairmen in the other MOSs. The decision was made (with SAG approval), therefore, to focus the research effort on only two major categories of maintenance training, regardless of MOS. These divisions were: (1) wheel and track vehicle maintenance, and (2) turret maintenance. This change in focus allowed a greater continuity and consistency of effort in the project.

Phases of training. Within the category of wheel and track vehicle maintenance, it was found that, regardless of the type of vehicle involved or the MOS for which the trainee was being trained, three general phases of training were common. These phases were: (1) a power plant phase, which includes gasoline, diesel, and multifuel engines; (2) a power train phase, including clutches, transmissions, etc.; and (3) a "systems" phase, which includes the electrical, fuel, brake, and other systems.

Within the category of turret maintenance, it was found that the training focused around the four primary types of systems found in a turret: armament, fire control, stabilization, and traversing/elevating. These systems are composed of electrical and/or hydraulic components, and the study of electrical and hydraulic systems is a major part of turret maintenance training.

Skill levels. Initial project planning centered around investigating maintenance training at both introductory and advanced skill levels. This distinction was discarded, however, in favor of one based on level of maintenance. For example, a 62B10 (Skill Level 1) mechanic is supervised by a 62B20 (Skill Level 2) mechanic, but they both perform organizational maintenance. Likewise, a 63H10 repairman is supervised by a 63H20 repairman, but they both perform DS/GS maintenance. It was concluded, therefore, that a clearer distinction existed between training content and training events for organizational maintenance and that for DS/GS maintenance than existed between introductory and advanced training. For these reasons, the organizational-DS/GS paradigm was used throughout the study. The two levels of maintenance of concern here--Organizational Maintenance and Direct Support/General Support (DS/GS) Maintenance--are defined as follows:

> Organizational Maintenance. Maintenance at this level is normally performed on line at the operational unit level and consists of both preventive and operational type maintenance tasks. It is directed toward daily readiness checks, diagnostic tests, lubrication, adjustments, and the capability for isolating, removing and replacing components or subassemblies with a minimum of effort or delay to the unit's operational mission.

> Direct Support/General Support (DS/GS) Maintenance. Maintenance at this higher echelon or level is performed primarily on equipment that has been removed from the vehicle because of parts failures. The primary function is to isolate the actual failed part of any component or subsystem, repair or replace the failed part, and then test and verify that the removed unit is satisfactory for return to stock. DS/GS maintenance units provide support to the combat units (e.g., to a tank company), but are not direct combat units themselves.

Task types. The wide variety of maintenance skills taught in the courses surveyed could be classified into three general types of tasks: motor, cognitive, and troubleshooting. These task types utilized here are not intended as a definitive task taxonomy in the formal sense. Rather, they are intended as a simple means of categorizing the various training objectives in a form that is manageable with reference to RPF device definition. The task types are defined as follows:

> Motor Tasks. Those tasks involving primarily physical manipulation of tools and/or equipment. Included in this category are such activities as removal and replacement of vehicle parts, assembly and disassembly of components, cleaning of parts, and loosening or tightening of nuts, bolts, screws, etc.

> Cognitive Tasks. Those tasks requiring primarily that the learner be in command of a particular body of cognitive knowledge. Included in this category are such activities as identification or recall of names, locations, facts, numbers, procedures, rules, and symbols. The possession of such information is an internal,

covert activity, and an external action or task (e.g., responding to a test question or pointing to an engine component) may be required to demonstrate the learner's level of cognitive knowledge.

Troubleshooting Tasks. These tasks require learners to combine both motor tasks and cognitive knowledge of a mechanical, hydraulic, or electrical system or component in the analysis of trouble symptoms and identification and repair of the malfunction indicated by the symptoms. This category of tasks can involve performance of various tests and calibrations, and requires skills in decision making. The learner is thus required to function at the higher cognitive levels of analysis, synthesis, and evaluation in order to perform these tasks.

The proportion of the tasks taught falling into each of these task types was determined by analyzing the objectives of the various courses as they were stated in the POIs. This analysis provided an indication of the relative emphasis placed on the various types of tasks trained in the institutional setting. Table A-1 shows the classification of task type for the various training objectives covered in the several courses as a function of category of training and level of maintenance. As can be seen, troubleshooting is a relatively important factor in all category-level combinations.

Table A-1

Objectives by Task-Category-Level

MAINTENANCE CATEGORY & LEVEL	TASK TYPE Motor	Cognitive	Trouble-shooting
Wheel & Track Vehicle; Organizational Level	56 [a]	1	43
Wheel & Track Vehicle; DS/GS Level	32	32	36
Turret; Organizational Level	49	5	46
Turret; DS/GS Level	58	5	37

[a] Numbers in table refer to percentage of training objectives taught falling in each maintenance category-level combination over all associated courses of instruction.

Areas of maintenance training. As a result of combining the two categories of maintenance (wheel/track vehicle and turret), the two levels of maintenance (organizational and DS/GS), the three general training phases common to the wheel/track vehicle maintenance courses (power plant, power train, and systems), and the three task types (motor, cognitive, and troubleshooting), some 24 major areas of maintenance training were identified for possible RPF device development. Of these, 18 concerned wheel/track vehicle maintenance, while six pertained to turret maintenance. These are shown in Tables A-2 and A-3, respectively.

Table A-2.

Areas of Wheel and Track Vehicle Maintenance Training

MAINTENANCE LEVEL	TRAINING PHASE	TASK TYPE Motor	Cognitive	Trouble-shooting
	Power Plant	Area 1	Area 2	Area 3
Organizational	Power Train	Area 4	Area 5	Area 6
	Systems	Area 7	Area 8	Area 9
	Power Plant	Area 10	Area 11	Area 12
DS/GS	Power Train	Area 13	Area 14	Area 15
	Systems	Area 16	Area 17	Area 18

Table A-3.

Areas of Turret Maintenance Training

MAINTENANCE LEVEL	TASK TYPE Motor	Cognitive	Trouble-shooting
Organizational	Area 19	Area 20	Area 21
DS/GS	Area 22	Area 23	Area 24

These 24 areas were rated (see Appendix C) to establish RPF developmental priorities for Tasks 3 and 4. Eventually, the following four subareas were chosen as the aspects of training in which to concentrate activities in Tasks 3 and 4: (1) troubleshooting engines and related systems at the organizational level; (2) troubleshooting track vehicle track/suspension systems at the organizational level; (3) removal/replacement of engines and power packs at the DS/GS level; and (4) troubleshooting turret electrical and hydraulic systems at both organizational and DS/GS levels.

DESCRIPTIONS OF COURSES SURVEYED

Twelve MOS-producing Army maintenance courses were covered in the Task 1 survey. This section of this appendix presents selected descriptive information about these courses. For each course the following items are given: Job (MOS) title; MOS number; training location; annual student load; purpose of course; mode of instruction; course length; and AETs used in the course.

1. Title: Construction Equipment Mechanic (Skill Level 1)

   MOS: 62B10

   Training Location: Fort Leonard Wood, MO

   Annual Student Load: 2000

   Purpose: To train enlisted personnel in the skills and knowledge necessary to perform organizational maintenance on wheeled and track construction equipment at skill level one of MOS 62B.

   Mode: Lock-Step

   Length: 6 weeks

   AETs Used: 1/4 ton, 2 1/2 ton and 5 ton trucks
   Cranes
   Dozers
   Rollers
   Graders
   Air compressors
   Also components from these end items. All end items are unserviceable vehicles.
   Air compressors used in three courses (62B10, 62B20, Warrant Officer Technician)

2. Title: Construction Equipment Mechanic (Skill Level 2)

   MOS: 62B20

   Training Location: Fort Leonard Wood, MO

   Annual Student Load: 250

   Purpose: To train enlisted personnel in the skills and knowledge necessary to perform organizational maintenance on wheeled and track construction equipment at skill level two of MOS 62B.

   Mode: Lock-step

   Length: 5 weeks

   AETs Used: Components only, taken from all types of construction equipment.

3. Title: Wheel Vehicle Mechanic

MOS: 63B10

Training Location: Fort Leonard Wood, MO

Annual Student Load: 2000

Purpose: To train enlisted personnel in the skills and knowledge necessary to perform organizational maintenance on automotive wheeled vehicles at skill level one of MOS 63B.

Mode: Self-paced

Length: 8 weeks

AETs Used: 1/4 ton, 2 1/2 ton and 5 ton trucks
Crane components
Dodge Power Wagons
Gama Goat

4. Title: Track Vehicle Mechanic

MOS: 63C10

Training Location: Ft. Knox, KY

Annual Student Load: 6000

Purpose: To train enlisted personnel in the skills and knowledge necessary to perform organizational maintenance on wheeled and track tank-automotive vehicles at skill level one of MOS 63C.

Mode: Lock-step

Length: 13 weeks

AETs Used: Wheeled phase
1/4 ton, 2 1/2 ton and 5 ton trucks
Gama Goats
Goers
Engines in test cells
Tracked phase
M109 self-propelled howitzers
M110 self-propelled howitzers
M113 armored personnel carriers
M60 tanks
M60A1, M60A2, and M551 tanks
M88 vehicle track recovery (heavy)
M578 vehicle track recovery (light)
Engines in test cells

5. Title: Fuel and Electrical Systems Repairman

MOS: 63G10

Training Location: Aberdeen Proving Ground, MD

Annual Student Load: 400

Purpose: To train enlisted personnel in the skills and knowledge necessary to perform direct and general support maintenance on fuel and electrical system components and brake systems. This course trains both skill levels one and two of MOS 63G.

Mode: Self-paced

Length: 12 weeks

AETs Used: Electrical and fuel systems components
Gasoline and diesel engines
1/4 ton trucks (lights, wiring, and brakes)

6. Title: Automotive Repairman (Skill Level 1)

MOS: 63H10

Training Location: Aberdeen Proving Ground, MD

Annual Student Load: 2500

Purpose: To train enlisted personnel in the skills and knowledge necessary to perform direct and general support maintenance on tank-automotive wheeled and tracked vehicles at skill level one of MOS 63H.

Mode: Self-paced

Length: 10 weeks

AETs Used:

Basic knowledge	- 1/4 ton trucks
Wheeled phase	- 2 1/2 ton and 5 ton trucks
Tracked phase	- M60A1, M60A2, M551 tanks Self-propelled howitzers Special purpose tracked vehicles

7. Title: Automotive Repairman (Skill Level 2)

MOS: 63H20

Training Location: Aberdeen Proving Ground, MD

Annua Student Load: 250

Purpose: To train enlisted personnel in the skills and knowledge necessary to perform direct and general support maintenance on tank-automotive wheeled and tracked vehicles at skill level two of MOS 63H.

Mode: Lock-step

Length: 11 weeks

AETs Used: No end-item vehicles
All bench-item components from wheeled and tracked vehicles

8. Title: Tank Turret Repairman (Skill Level 1)

MOS: 45K10

Training Location: Aberdeen Proving Ground, MD

Annual Student Load: 600

Purpose: To train enlisted personnel in the skills and knowledge necessary to perform direct and general support maintenance on tank turrets, armored reconnaissance vehicles, and armored personnel carrier cupolas at skill level one of MOS 45K.

Mode: Lock-step

Length: 8 weeks

AETs Used: M60A1 tank turrets
M60A2 tank turrets
M551 tank turrets and gun tubes
M551 tank
M27 cupolas

9. Title: Tank Turret Repairman (Skill Level 2)

MOS: 45K20

Training Location: Aberdeen Proving Ground, MD

Annual Student Load: 15

Purpose: To train enlisted personnel in the skills and knowledge necessary to perform direct and general support maintenance on tank turrets, armored reconnaissance vehicles, and armored personnel carrier cupolas at skill level two of MOS 45K.

Mode: Lock-step

Length: 16 weeks

AETs Used: M60A1, M60A2, and M551 tank turrets and gun tubes

10. Title: Tank Turret Mechanic

MOS: 45N10

Training Location: Ft. Knox, KY

Annual Student Load: 300

Purpose: To train enlisted personnel in the skills and knowledge necessary to perform organizational maintenance on tank turret systems at skill level one of MOS 45N.

Mode: Lock-step

Length: 8 1/2 weeks

AETs Used: M60A1 tank turrets
M60A1 turret trainers (cut-away turrets)

11. Title: Sheridan Turret Mechanic

MOS: 45P10

Training Location: Ft. Knox, KY

Annual Student Load: 200

Purpose: To train enlisted personnel in the skills and knowledge necessary to perform organizational maintenance on M551 series AR/AAV turret systems at skill level one of MOS 45P.

Mode: Lock-step

Length: 8 1/2 weeks

AETs Used: M551 tank turrets

12. Title: Missile Tank Turret Mechanic

MOS: 45R10

Training Location: Ft. Knox, KY

Annual Student Load: 25

Purpose: To train enlisted personnel in the skills and knowledge necessary to perform organizational maintenance on M60A2 tank turret systems at skill level one of MOS 45R.

Mode: Lock-step

Length: 11½ weeks

AETs Used: M60A2 tank turrets
M60A2 turret trainers (cut-away turrets)

APPENDIX B

SURVEY PROCEDURE

This appendix describes the general procedure used in the field survey of selected Army and non-Army maintenance training sites that comprised Task 1. The principal purpose of the survey was to identify current maintenance training practices, including the devices used to support that training, in order to provide the information required for subsequent tasks. More specifically, the survey information was necessary to the selection of training areas in which possible development of RPF alternatives to AET devices would be explored.

The first section of this appendix describes the general survey procedure and lists the places and persons surveyed. The second section presents the interview guide used in the survey, while the third section presents certain general observations related to the survey and resulting data. Further information concerning the specific Army training courses examined in the survey is contained in Appendix A.

PROCEDURE

General Procedure

The general procedure followed in the survey was to conduct a series of interviews with the personnel responsible for the management of the maintenance training courses of concern and, wherever possible, with the personnel actually administering the instruction. When time and circumstances permitted, the survey team observed first-hand the instructional segments in which the AET devices were being used. Interviews were administered using a structured interview guide. Advance coordination with interviewees was effected through telephonic contact and the transmission of official messages.

As can be seen from review of the interview guide in the next section of this appendix, the major areas of concern in the interview were as follows:

- Types of AETs and the extent of their use
- Skills/tasks taught with the AETs
- Course information
- Trainee information

The time required to conduct the interviews varied depending upon the context of the interview. Persons in authority such as division chiefs and training directors were asked to respond to the entire guide, and this generally consumed about one hour. When observing the instruction taking place in the shops, only those items dealing with AET usage, skills/tasks taught, method of measurement and problem areas were asked of the instructors. These items consumed as little as one or two minutes and as much as 20 minutes, depending on how much time the instructor had available and how much detail he provided.

Army Courses Surveyed

Three major Army training centers were visited and 12 courses were surveyed. Listed below are the three centers and the courses surveyed at each, identified by MOS number and name.

1. U.S. ARMY ORDNANCE AND CHEMICAL CENTER AND SCHOOL
   ABERDEEN PROVING GROUND, MARYLAND

   - MOS 63H10 Automotive Repairman (Skill Level 1)
   - MOS 63H20 Automotive Repairman (Skill Level 2)
   - MOS 63G10 Fuel and Electrical Systems Repairman
   - MOS 45K10 Tank Turret Repairman (Skill Level 1)
   - MOS 45K20 Tank Turret Repairman (Skill Level 2)

2. U.S. ARMY ARMOR SCHOOL
   FORT KNOX, KENTUCKY

   - MOS 45N10 Tank Turret Mechanic
   - MOS 45P10 Sheridan Turret Mechanic
   - MOS 45R10 Missile Tank Turret Mechanic
   - MOS 63C10 Track Vehicle Mechanic

3. U.S. ARMY TRAINING CENTER
   FORT LEONARD WOOD, MISSOURI

   - MOS 62B10 Engineer Equipment Mechanic (Skill Level 1)
   - MOS 62B20 Engineer Equipment Mechanic (Skill Level 2)
   - MOS 63B10 Wheel Vehicle Mechanic

The following personnel were contacted during the survey:

1. U.S. ARMY ORDNANCE AND CHEMICAL CENTER AND SCHOOL (ABERDEEN)

   - Training Development - Mr. Seese & Miss Gaventer
   - TASO - Mr. Dees
   - 63H10 - MAJ Franks, Division Chief
     SGT Tukums, Branch Chief
     SGT Jones & SGT Kelly, Senior Instructors
   - 63H20 - SGT Doss, Senior Instructor

- 63G10 - CPT Murphy, Division Chief
  CW4 Brady, Branch Chief

- 45K10 - CPT Dyson, Branch Chief
  SGT Owens, Senior Instructor

- 45K20 - SGT Chappel (USMC), & SGT Langley, Senior Instructors

2. U.S. ARMY ARMOR SCHOOL (FORT KNOX)

- 45N10 - Mr. Manning, Branch Chief

- 45P10 - Mr. Pierce, Branch Chief

- 45R10 - Mr. Szczapinski, Branch Chief

- 63C10 - MAJ Lynn, Division Chief
  MAJ Randles, Operations Officer
  Mr. Bateman, Engine and Electric Division

3. U.S. ARMY TRAINING CENTER (FORT LEONARD WOOD)

- CAPT Trien, Training Command
  Mr. Edmondson, Training Development

- 62B10 - LT Craig, Company Commander
  CW3 Viau, Course Chief

- 62B20 - CW3 Staton, Course Chief

- 63B10 - LT Allaben, Officer in Charge
  SGT Reigle & SGT South, Senior Instructors

Non-Army Courses Surveyed

A corollary effort of Task 1 was an investigation of maintenance training practices of selected commercial and non-Army military agencies. Maintenance training at several such sites was observed to determine if RPF alternatives already existed in the areas of training where the Army is currently using AETs. The purpose of this effort was to establish a basis for comparing Army practices with the practices of non-Army agencies engaged in simi r areas of maintenance training. The non-Army agencies and specific areas of training surveyed were:

1. U.S. AIR FORCE
   CHANUTE AIR FORCE BASE, RANTOUL, ILLINOIS

   - Base Vehicle Mechanic
   - Special Vehicle Mechanic

2. U.S. NAVY
   NAVAL CONSTRUCTION TRAINING CENTER, GULFPORT, MISSISSIPPI

   - Construction Mechanic, A, J, and C Schools

3. MOTECH AUTOMOTIVE EDUCATION CENTER
   LIVONIA, MICHIGAN

   - Automotive Service and Body Repair

4. JOHN DEERE CENTRAL DIVISION
   MEMPHIS, TENNESSEE

   - Heavy Equipment Maintenance

5. ATLANTA AREA TECHNICAL SCHOOL
   ATLANTA, GEORGIA

   - Automotive Mechanic

Personnel contacted at these non-Army sites included:

1. CHANUTE AFB

   - COL Yeabower, School Commander
   - Mr. Carter, Civilian Advisor to Commander
   - Mr. Harper, Training Department
   - SGT Patterson & SGT Bloomer, Instructors

2. NAVAL CONSTRUCTION TRAINING CENTER

   - CDR Griffith, Commanding Officer
   - CWO3 Hays, Equipment Schools Department Head
   - Chief Seiler, Senior Instructor
   - Mr. Matthews, Training Department

3. MOTECH AUTOMOTIVE EDUCATION CENTER

   - Mr. Vorasco, Chief Instructor
   - Mr. Haight, Instructional Developer

4. JOHN DEERE CENTRAL DIVISION

   - Mr. Love, Service Manager
   - Mr. Phillips, Instructor/Instructional Developer

5. ATLANTA AREA TECHNICAL SCHOOL

   - Mr. Friedman, Instructional Specialist

INTERVIEW GUIDE

1. Training Location
2. Name/Rank/Position of Respondent
3. Course
4. Method of Instruction (Lock-Step or Self-Paced)
5. Annual Trainee Flow
6. Trainee Characteristics
   - Age
   - Education level
   - Reading level
   - Time in Army
   - Attrition rate
7. Availability of:
   - Task List
   - POI
   - Soldiers Manual
   - SQT
8. How trainee performance is measured
   - Written tests
   - Performance exams
9. Trainee Movement Through Course
   - Sequence
   - Time
10. Significant Problem Areas or Areas Difficult to Teach/Reasons
    - Equipment constraints
    - Lack of equipment
    - Equipment not suitable for training
    - Time constraints
    - Trainee flow
    - Task complexity
    - Subject-matter difficulty
    - Trainees' lack of ability
11. Percent of Instruction that is Hands-On
    - Classroom instruction
    - Shop instruction
12. AETs Used in Course/Cost/Origin
    - Classroom
    - Shop
13. Skills/Tasks Taught with AETs
    - Cognitive
      - Identification of parts
      - Location of parts
      - Theory of operation
      - Sequences/procedures
    - Motor
      - Removal/replacement
      - Adjustment
    - Troubleshooting
      - Testing
      - Problem identification
      - Fault isolation
      - Prescription of corrective procedures

OBSERVATIONS

In the conduct of the Task 1 survey specific data were gathered and a variety of less formal observations were made. In general, the nature of the maintenance training observed can be described as (1) lock-step, (2) emphasizing system theory, and (3) placing heavy reliance on the use of AETs. There were some exceptions, of course, but the support for the use of actual equipment in training was virtually unanimous. Also, there was little or no difference of consequence between the Army and non-Army maintenance training courses observed.

The following statements briefly treat several of the areas of concern in the survey. It should be noted that these statements refer only to the Army training courses.

Task and Skills Analysis Basis

The investigators in this study were asked to determine the task and skills analysis basis for the maintenance training programs examined, particularly the relationship of training to the critical maintenance tasks represented in Skill Qualification Tests (SQTs). The interest was the extent to which these skills would be reflected in the intended uses of AET devices examined. It was found that at the time of the survey no SQTs had been developed for the 12 MOSs surveyed and that Soldier's Manuals existed for only six of those MOSs. New POIs related to the critical task list for any particular MOS had not yet been developed, and the POIs in use were based on the TRADOC systems engineering effort of several years ago. As a consequence, none of the POIs, even in the courses where Solider's Manuals were available, was directly related to a critical task list or a Soldier's Manual. Therefore, no particular correlation was observed between critical task lists and the intended uses of the AET devices examined.

Extent of Usage of AETs

Approximately 90% of the maintenance training observed was conducted with actual end-item equipment as the primary training device, with virtually all of that 90% involving the teaching of motor and troubleshooting tasks. This extent of usage of AETs was common in both organizational and DS/GS training. The remainder of the instruction, particularly the teaching of cognitive tasks, was conducted using a variety of audio-visual media and/or panel boards constructed with actual components from vehicle systems, most of which were locally fabricated for a specific course. Few commercially produced training aids were observed, and they were usually manufacturer-built cutaway engines or other vehicle components which also are technically defined as AETs.

Intended and Actual Usage of AETs

Approximately 75% of the AETs used in the courses observed were, due to age and/or damage, items of equipment not usable in the units and dedicated solely to maintenance training. Once the equipment is found to be nonfunctional for unit use and dedicated to maintenance training, it is rarely used for any other purpose. The investigators in this study found no great discrepancy between intended and actual uses of AETs used for maintenance training.

Multiple Uses of AETs

In the maintenance training observed, the trainees moved from shop to shop as they progressed through their training. The AETs used in each phase were usually dedicated to that phase, and use of an individual AET for more than one phase of training was rare. An exception was found in the MOS 62B10/20 Engineer Equipment Mechanic courses at Fort Leonard Wood. The air compressors used in that phase of training were also used in Warrant Officer's courses that are taught in the same facilities.

It was found, however, that multiple uses of classes of AETs (as opposed to individual items of equipment) was a common practice. An example is the M151 quarter-ton truck, commonly known as the Jeep. This vehicle is readily available in very large numbers and is used for basic instruction in a wide variety of task areas, particularly in troubleshooting and repair of fuel, electrical, and brake systems. Multiple use of other classes of vehicles, especially the various weight levels of large trucks, apparently is also widespread throughout Army maintenance training.

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APPENDIX C

SELECTION OF HIGH-INTEREST TRAINING AREAS

This appendix describes the manner in which specific areas of maintenance training were selected for the development of possible RPF devices. This selection process was the focus of Task 2 of the overall effort.

As described in the basic report and in Appendix A, there were some 24 areas or domains of maintenance training resulting from the various combinations of (a) training category, (b) maintenance level, (c) instructional phase, and (d) task type. The goal of Task 2 was to identify areas among these 24 that would be of highest interest to the Army with reference to future development of RPF alternatives to AETs.

Two types of activities were involved in Task 2. First, a method for rating the 24 instructional areas was devised and applied in order to allow establishment of a priority ordering. Second, based on these ratings, four of the 24 areas were selected and recommended to the SAG as the areas in which to pursue RPF device conceptual development in Tasks 3 and 4.

Six dimensions were identified as especially pertinent to the selection of areas for RPF device development. These were: (1) skill complexity; (2) subject-matter difficulty; (3) commonality to other courses; (4) trainee volume; (5) AET effectiveness as a teaching aid; and (6) AET cost. These dimensions were defined as follows:

A. Skill complexity. Factors considered here were the degree of complexity required in the manipulation of tools and equipment, the sophistication of those tools and equipment, and the amount and nature of the cognitive knowledge required to perform the skill.

B. Subject-matter difficulty. Considered here were the ability level of the trainees, the degree to which the skill or knowledge is abstract rather than concrete, the complexity of the interrelationships between equipment systems and/or subsystems, and the reading level of course materials or manuals.

C. Commonality to other courses. The primary element in this dimension was the percentage of the courses observed in which a particular skill was taught. If the skill was taught in 80% or more of the courses, it was rated Very High on commonality. It was rated High if taught in 60-79% of the courses; Moderate if taught in 40-59% of the courses; Low if taught in 20-39% of the courses; and Very Low if taught in less than 20% of the courses observed.

D. Trainee volume. The annual volume of trainees flowing through a course was the determining factor here. The ratings were as follows: Very High = 5,000 or more trainees per year; High = 3,000-4,999 trainees per year; Moderate = 1,000-2,999 trainees per year; Low = 500-999 trainees per year; and Very Low = less than 500 trainees per year.

E. Effectiveness of AET as a teaching aid. Considerations included the AFT's ability to display the system being studied, noise level, safety, ability to demonstrate a range of malfunctions, ease of insertion of malfunctions, ease of use for multiple tasks, ability to withstand heavy use, adaptability to engineering changes, ability to measure trainee performance, ability to provide feedback to the trainee, and presence of features specifically designed to enhance training.

F. AET cost. In this category, Very High = $100,000 and over; High = $50,000-$99,999; Moderate = $10,000-$49,999; Low = $5,000-$9,999; Very Low = less than $5,000.

Based on the interview data developed in Task 1, the on-site observations of the various AET devices and their use in training, and the variety of other material[1/] gathered relevant to Army maintenance and training, the research team assigned five-point rating scale values to each of the six dimensions identified for each of the 24 training domains. The five-point scale was as follows: 1 = Very High; 2 = High; 3 = Moderate; 4 = Low; and 5 = Very Low. In applying this rating scale to the six dimensions, a degree of subjectivity was necessarily present on some dimensions, while others were relatively objective.

The results of this rating procedure for wheel and track vehicle maintenance training are shown in Table C-1, while those for turret maintenance training are given in Table C-2. In developing these ratings, the research staff discussed each factor and area separately in light of the survey data and experience and then arrived at a group consensus rating. Thus, the numbers shown in Tables C-1 and C-2 represent the best collective judgments of the research team resulting from these discussions.

Based on the ratings and other pertinent considerations, the research team recommended to the SAG that RPF device development be focused on instructional segments falling within four of the 24 instructional domains. The four areas were: (1) troubleshooting tasks, power plants, organizational level wheel and track vehicle mechanic; (2) troubleshooting tasks, power train, organizational level wheel and track vehicle mechanics; (3) motor tasks, power plant, DS/GS level wheel and track vehicle mechanics; and (4) troubleshooting tasks, both organizational and DS/GS level turret mechanics. The particular instructional segments ultimately selected for Tasks 3 and 4 were taken from these four instructional areas. More specifically, the instructional segments selected in each of these four areas were as follows:

[1/] Such material included course syllabi and programs of instruction, lesson plans, task lists, Soldier's Manuals, Skill Qualification Tests, device costs, student flow, and similar training or information items.

Table C-1.

Ratings of Areas of Wheel and Track Vehicle Maintenance Training

MAINTENANCE LEVEL	INSTRUCTIONAL PHASE	TASK TYPE AND RATING FACTOR																	
		Motor						Cognitive						Trblshtng					
		A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
Organizational	Power Plant	3	4	1	1	2	2	3	3	1	1	2	2	2	1	1	1	3	2
	Power Train	4	4	1	1	2	2	4	2	1	1	2	2	2	2	1	1	3	2
	Systems	4	3	1	1	3	2	3	3	1	1	3	2	2	2	2	3	4	3
DS/GS	Power Plant	3	4	1	2	3	1	3	3	2	2	3	1	2	2	1	2	4	1
	Power Train	3	4	1	2	3	1	3	3	2	2	3	1	3	2	2	3	4	1
	Systems	3	4	1	2	4	2	3	3	2	2	3	2	2	2	1	2	4	1

Table C-2.

Ratings of Areas of Turret Maintenance Training

SKILL LEVEL	TASK TYPE AND RATING FACTOR																	
	Motor						Cognitive						Trblshtng					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
Organizational	4	4	1	4	4	1	3	3	1	4	3	1	1	1	1	4	4	1
DS/GS	4	4	1	4	4	1	3	3	1	4	3	1	1	1	1	4	4	1

Key:

Scale Value
- 1 = Very High
- 2 = High
- 3 = Moderate
- 4 = Low
- 5 = Very Low

Factor
- A = Skill Complexity
- B = Subject-Matter Difficulty
- C = Commonality to Other Courses
- D = Student Volume
- E = Effectiveness of AET as Teaching Aid
- F = AET Cost

- Area 1 - Troubleshooting engines and related systems
- Area 2 - Troubleshooting track vehicle track/suspension systems
- Area 3 - Removal/replacement of engines and power packs
- Area 4 - Troubleshooting turret electrical and hydraulic systems.

These segments were recommended to the SAG as the basis for Tasks 3 and 4 activity. The SAG concurred in this selection, and Tasks 3 and 4 proceeded accordingly.

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APPENDIX D

EVALUATION OF RPF DEVICES

The devices discussed in Section III can be acceptable to the Army only if they are effective in preparing trainees to perform required maintenance tasks on the job. To achieve this goal, the trainee must acquire equipment skills necessary to perform the maintenance tasks, and the cognitive knowledge necessary to guide the implementation of the skills. The training device thus must contribute to both skill acquisition and understanding of the equipment.

While training effectiveness is a requirement for a training device, an additional consideration is its cost effectiveness. Acceptable levels of trainee performance must be achieved at a minimum training cost. The evaluation of a device, therefore, must incorporate both training effectiveness and cost effectiveness measures.

The Army has standard procedures[1/] for identifying cost factors related to training devices and for incorporating them into training cost analyses to determine user value. Hence, the focus of the evaluation methodology developed here is on determining device training effectiveness. More specifically, the focus is on determining the comparative effectiveness of alternative RPF devices and AETs.

This Appendix is addressed primarily to persons who will be responsible for device evaluations. It presents an outline of a methodology that can be adapted to the evaluation of any of the devices discussed in Section III. Because the methodology must be general enough to include all those devices, and because they will be evaluated under varying conditions, details of many specific procedures cannot be given. Even so, the methodology is comprehensive, and the discussion addresses technical issues that will require expert adaptations to the specific requirements of separate applications. The team who will conduct the evaluations thus must include the experts needed to make the adaptations.

In addition to this introduction, this Appendix includes three major sections. The first section presents an instructional context for the evaluations, with special emphasis upon the structure of training program evaluations. The second section develops the evaluation procedures. The third section identifies the technical capabilities that must be represented on the evaluation team.

In addition to these three sections, three addenda appear at the end of this Appendix. These addenda present separate specimen questionnaires to be given to trainees, their AIT instructors, and the trainees' job supervisors after unit assignment. The specimen questionnaires concern gasoline engine

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[1/] Cost and Training Effectiveness Analysis. TRADOC Pamphlet 71-10 (Draft), Headquarters, U.S. Army Training and Doctrine Command, Ft. Monroe, Va., 1977.

maintenance and repair, and suitable adaptations will be required for other types of maintenance training.

INSTRUCTIONAL CONTEXT FOR THE EVALUATION

The evaluation of a training device can be viewed within the context of training course development. Various branches of the military have jointly developed a set of procedures, commonly referred to as ISD,[1] which includes seven major steps to be followed in conceiving, developing, implementing, and evaluating a training course. These steps will not be detailed here. Instead, eight related or derivative procedural steps of particular concern in training course evaluations will be identified and discussed briefly. Five of these steps will be discussed in detail in the section that follows.

The eight procedural steps for evaluations are as follows:

1. Statement of the problem. The evaluation problem as it applies to the particular case at hand must state clearly the issues to be resolved, and in such a manner that requirements for the remaining procedural considerations are clearly determined. The source of the problem, and implicit in its statement, should provide a framework for interpreting findings and deriving adaptive actions based on the findings.

2. Analysis of cognitive and manipulative skills to be taught. Specific training objectives for the course of concern must be stated in terms of those knowledges and skills required for job performance, and for which trainees are to be prepared in the course.

3. Development of the training course. This step encompasses the design of the instructional process whereby course objectives are to be achieved. Of particular concern for the present effort is the assurance that the instructional program is designed to capitalize on the specific training capabilities of the various devices being used.

4. Selection of criterion measures. Psychometrically sound measuring instruments and procedures must be available for determining as objectively as possible the extent to which course objectives are achieved by trainees. In the context of device evaluation, it is especially important that measures of device-relevant objectives be those which the device, by design and utilization, can help achieve. In addition to measuring trainee achievements, the evaluation of a device requires information regarding device use and its acceptance by users.

5. Design of the evaluation. All independent variables of concern in the evaluation must be identified and their roles must be implemented in such a way that the data to be collected reflect clearly the effects of each such variable. In addition, provisions must be made for controlling the effects

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[1] Interservice Procedures for Instructional Systems Development. TRADOC Pamphlet 350-30, Headquarters, U.S. Army Training and Doctrine Command, Ft. Monroe, Va., 1 August, 1975.

effects of variables that are not in themselves of concern, but which, if not controlled, can prevent a clear identification of effects of the independent variables.

6. Collection of data. This step must provide for the administration of all measuring instruments. The sources of data must be specified and a schedule for the collection established.

7. Analysis of data. Certain specific aspects of data analysis must be determined by the types of data available, and by the results of other data analyses. Nevertheless, the structure for examining data should be clear at the outset, and a basic analytic schema established.

8. Integration of findings vis-à-vis the evaluation problem. As stated in connection with 1 above, a framework for interpreting findings, and for deriving adaptive actions based on them, should be the source of the problem statement originally. Hence, the procedures involved in this step are to be directed toward resolving issues which gave rise to the evaluation effort, using the information obtained from that effort.

EVALUATION PROCEDURES

Three of the procedural steps above go beyond the scope of the present effort. Specifically, Steps 2, 3, and 8 will be part of the final evaluation effort, and the previously referenced ISD procedures provide adequate guides for their completion. Hence, they will not be discussed further in this report except for general considerations concerning them as they apply to the remaining steps.

Steps 1 and 4-7, or certain aspects of them, are of particular concern in this project, however. They, too, are included in ISD procedures, but Task 5 of this project calls for adapting these steps to the unique problems of evaluating the maintenance training devices identified in this report. The remaining parts of this section will discuss these five steps in order, focusing upon their adaptations to the evaluation of the maintenance training devices.

Statement of the Problem

This step has two facets, as pointed out above. The first is to provide a guide for deriving the remaining procedural steps; and, second, by its derivation, it should provide a framework for interpreting evaluative data and for determining adaptive actions based on the data. The second facet is covered in the main text of this report, specifically in Section I in discussions of the need for better, cost-effective maintenance training, the military problem of providing such training, and the research problem prompted by the need and the military's reaction to it.

The first facet of the problem statement is a clear definition of the issues to be resolved, stated so as to establish requirements for the remaining procedural steps. For present purposes, the problem is to determine the training effectiveness of certain alternative maintenance training devices relative to corresponding AETs and, in some cases, to alternative devices. The problem requires that research procedures be established for answering, or otherwise resolving, seven questions regarding training.

These questions are:

1. What kinds of measures can be used that are indicative of training effectiveness?

2. From what sources, under what conditions, and from whom should these measures be obtained?

3. How are the measures to be analyzed so as to provide comparative indices of RPF and AET training effectiveness?

4. Is the effectiveness of a device, including AET, dependent upon certain instructional modes?

5. Is the effectiveness of a device per se, or its use in alternative instructional modes, dependent upon certain student characteristics such as aptitude level or amount of relevant experience?

6. Because instructors may vary in the effectiveness with which they use various devices in training, how are instructor effects to be provided for in the analyses?

7. Because training sites may differ in ways affecting device use and training value, how are the effects of these differences to be determined or otherwise provided for in the analyses?

As it applies to the present problem, question 1 is answered in the subsection that follows. The various aspects of question 2 are treated in the next subsection, as is question 6. The remaining questions then are addressed in the following subsection.

Selection of Criterion Measures

The primary concern in evaluating training devices is the adequacy of on-the-job performance of graduates of training programs that use the devices. It is necessary therefore that job competence of graduates be assessed, and in a manner that reveals the adequacies, and lacks thereof, of devices used in preparing them for unit responsibilities. Time constraints require that such assessments be made soon after prototype training devices become available, for decisions regarding the procurement of additional devices must be made without undue delay. Hence, job performance measures that are revealing of competence, and that can be obtained relatively soon after training, must be used.

A second set of measures, a group administered during and immediately upon completion of AIT, should also be obtained. Such measures can reveal specific strengths and weaknesses of training programs according to attainments of particular training objectives. These indicators would not only reveal trainee achievement during training as it relates to device use, but to the extent that such achievement is predictive of later job performance, they provide data within the time constraint that can be used in decisions regarding device procurement.

Thus, these two sets of measures, one of job performance and the other of AIT achievement, will permit evaluations of devices as they affect both the achievement of particular AIT objectives per se, and the transfer of knowledge and skills related to these objectives to the complex integrations of behaviors required for adequate job performance. 1/

The kinds of measures required for these dual evaluations are discussed in detail below. Also, separate discussions are devoted to two other types of measures that will be needed. One concerns user acceptance of the devices and the training programs in which they are used. The second type of additional measure concerns information regarding device use and characteristics which can aid in interpreting device effects on training, and can provide inputs for cost analyses.

<u>AIT achievement measures</u>. To be useful for evaluating training devices, measures obtained during or at the end of AIT (as well as measures of job performance must satisfy two criteria: (1) they should focus upon aspects of achievement which are relevant to device design and utilization; and (2) they should be psychometrically sound. The application of these criteria will be discussed briefly before turning to the nature of the AIT measures themselves.

The devices to be evaluated will be used for only certain segments (e.g., gasoline engine maintenance) of overall AIT training. Furthermore, among the training objectives included in these particular segments, the achievement of only certain ones can reasonably be expected to be enhanced by given devices. Hence, at the outset, device-relevant objectives should be identified, and provisions should be made for separating measures of their attainment from measures concerned with objectives not related to the purposes implied by device design and use. Device-relevant measures can be administered along with the others, however; the requirement is only that they be quantitatively distinguishable.

The second criterion, psychometrical soundness, applies not only to AIT achievement and job performance measures, but to all measures obtained for the evaluations. It should be ascertained that each separate measurement item or procedure of concern is conceived and formulated in a way to assure validity and objectivity in measuring the particular objective for the item or procedure. Generally, validity can be attained by appropriate logical extensions of separate training objectives into statements of observable behavior or other relevant manifestations. Objectivity is usually attained to the extent that the manifestations can be observed and quantified unambiguously.

1/ Certain devices may on occasion be used for unit training as well as for AIT. In such cases, points made relative to AIT would need adapting to the requirements and conditions of unit courses.

Exceptions to rigorous objectivity should be restricted primarily to measures obtained through questionnaires. As discussed elsewhere, instruments of this type are to be used to measure user acceptance of training programs, some aspects of training achievement and on-the-job performance, and certain other relevant variables. The information to be obtained is inherently subjective. It is imperative therefore that schemata for recording data provide for maximum reliability of subjective reports. Both the instruments for recording these judgments, and the instructions accompanying them, should help the responder focus on clear-cut characteristics to be rated, and provide meaningful criteria for assigning ratings.

Two types of achievement should be measured during or at the end of AIT, knowledge or cognitive skills, and manipulative or hands-on skills. The former skills include theory of equipment construction and functioning, as well as those aspects of procedural knowledge required to guide the application of hands-on skills. The hands-on skills include all relevant manipulative actions that must be taken to complete given maintenance tasks.

Both types of achievement are currently measured in existing training programs, and it is likely that some measures as now obtained could be readily adapted to evaluations of training devices. However, the criterion of device relevance should be applied in their selection and modification as discussed above. It is also likely that some device-relevant objectives are not measured by existing tests. This lack could be due to objectives important for device evaluations simply being omitted from samples of achievement areas covered by existing tests. Or, the lack may be because certain devices make practicable the achievement of objectives not included in existing courses. In either case, entirely new test items and procedures would have to be developed, for the instruments and procedures finally used for evaluation should tap all important device-relevant objectives.

Once relevant objectives are identified, both existing test items, and new ones as needed, should be examined for psychometrical soundness. Generally, each objective should be logically extended to observable, quantifiable manifestations. For example, an objective might state that a trainee will be able to identify symptoms of a fuel system malfunction. If this objective is achieved, the trainee should also be able to state the nature of these symptoms when properly questioned, or to recognize and discriminate their occurrence in a malfunctioning AET or as simulated in an RPF. In either case, measures could be derived as the number of symptoms correctly identified, the number of inapplicable symptoms falsely identified, and/or the numbers of instances in which target symptoms are confused with irrelevant ones. Thus, the trainees' achievement could be quantified as numbers of errors or of appropriate identifications. The length of time required to identify symptoms would also reflect some aspects of achievement. Furthermore, for training objectives permitting clear-cut categorical assessment (e.g., go/no-go decisions for a series of objectives to be attained in sequence), rate-based measures can provide the necessary quantification. Possibilities include time required per objective attainment, number of attainments per unit of time, or simply the total number of objectives achieved during the portion of the course devoted to relevant topics.

Job performance measures. Adequacy of job performance is only partially determined by cognitive and hands-on skills per se. Such skills are necessary, but not sufficient by themselves, because they must be integrated into appropriate judgements and actions as determined by the cues and demands of real-world situations. In addition, the graduate trainee is expected to progress on the job beyond the achievement levels attained in AIT. Hence, indicators of job performance must tap capabilities and actions that cannot be observed during AIT.

This is not to say that AIT types of achievement should not be measured on the job. Information regarding the retention of skills learned in earlier training is needed to help interpret the more complex aspects of job performance. For example, the extent to which previous learning can be integrated appropriately for real-world performance will depend on its retention in some form, so the relative permanence of AIT learning should be determined for each training program. Furthermore, subsequent learning on the job will depend to some, probably a great, extent upon retention of previous knowledge on which to build.

Thus, evaluative measures obtained on the job should focus both on cognitive and hands-on achievement as in AIT, and on the more complex aspects of operational competence. (It is recognized that scores on the latter measures will be determined by factors such as trainee motivation and attitudes toward their job responsibilities, and that such influences can represent "noise" in measures. Nevertheless, these influences can be minimized, or otherwise controlled, by judicious selections of behaviors to be measured. To the extent that job motivation and attitudes reflect effectiveness of training, these influences would, of course, not be considered noise.)

As stated above, cognitive and hands-on achievement should be assessed on the job. The Skill Qualification Test (SQT), normally administered six months after completing AIT, is one readily available source for such measures. However, other achievement measures should be obtained approximately two months following AIT. These latter measures will probably reflect AIT achievement less ambiguously, in that AIT and job learning will be less confounded. For comparability of data, it would be desirable at this two-month point to include a pencil-and-paper test similar to that used in AIT for retention of cognitive learning, as well as measures of hands-on skills which overlap with those used in AIT.

Because of its complex nature, job performance beyond individual manipulative skills must be measured according to criteria that reflect that complexity. Expansion of job capabilities as mentioned earlier can be assessed via questionnaires completed by supervisors. For example, current skills or skill levels not evident at the beginning of unit assignment could be identified by a listing of the numerous relevant skills needed for job performance, with a rating scale for each on which growth in competence could be indicated. Other questions could be designed to identify specific trainee strengths and weaknesses, the supervisors' overall evaluations of or confidence in the trainees' capabilities, etc. In addition to supervisors' evaluations, analogous self-evaluations by trainees should be obtained. (Items illustrating these types of measures appear in the specimen questionnaires in Addenda 1 and 3 to this Appendix.)

In addition, a number of objective measures could be used to assess job performance if they are determined under standard conditions. Number of attempts or time required to successfully complete a maintenance task; downtime of vehicles needing repair; immediate recurrence of similar symptoms of malfunctions following equipment repair, or occurrence of other symptoms that indicate inadequate repair; checks and confirmations by supervisors that a system has been adjusted or repaired to a specified maintenance level; numbers of system components returned from the field for repair that do not actually need it--these and other objective indicators can provide evidence of adequacy of performance. However, such measures can be useful only if individual responsibility for the related actions can be established. Hence, procedures for gathering such data must permit identification of individuals involved and their separate roles.

Specifications for individual measures must await the task analyses and the establishment of training requirements referred to earlier. Whatever form they finally take, however, they should conform to the criteria of device relevance and psychometric soundness.

User acceptance measures. The focus for user acceptance measures should be upon the satisfaction of trainees and instructors with training devices used, and upon job supervisors' satisfaction with trainees after training. Because the value of devices depends to a great extent upon how they are used, acceptance measures should also reflect satisfaction with the relevant segments of the training program as well.

Device acceptance by trainees, instructors, and, by implication, supervisors is of concern for two reasons. First, it is important, although perhaps not crucial, for morale that users of given programs and media see them as valuable and their roles in them as satisfying. Second, in the event that a training device is or could be training effective, but generally is not seen as satisfactory by groups of users, establishing its nonacceptability would provide a signal for possible device design changes or for needed managerial actions directed toward educating the users regarding the device's value.

Most, if not all, data concerning user acceptance should be gathered through carefully constructed questionnaires. Each of the three specimen questionnaires that appear as addenda to this Appendix provides for such measures. The questions for instructors are the most detailed, because they will know about aspects of device design and use that trainees and supervisors will not know. The questions for supervisors are necessarily general, related to overall quality of training, because they may not even know that a device was used in AIT.

As illustrated in the specimen questionnaires, user acceptance measures would be part of the same instruments used to gather data for some job performance evaluations, and for other facets of the evaluation discussed in the next paragraph.

Additional measures needed. Other types of data, specifically regarding device use, will be needed for an adequate evaluation of each device. These data can serve two purposes. Some can provide information that will aid in interpreting various results of training effectiveness analyses. A second group of measures can provide input for certain training cost analyses.

Data that can aid in interpreting effects of training include trainee attrition rate; amount and nature of device use; instructors' and trainees' evaluations of devices; level, depth, and comprehensiveness of training attempted with the aid of devices; adequacy of software used with devices; amount and nature of instructor effort required; etc. Such data may also reflect user acceptance. Data such as attrition rate can be obtained from school records. Much of the other information can be gathered with questionnaires as illustrated in Addenda 1 and 2 to this Appendix.

Data needed for cost analyses include mean time required to complete each program, which is of special interest in comparing lock-step and individually paced programs; numbers of instructors and amounts of instructor effort required in the various programs; equipment set-up time; etc. Some measures of these sorts are included in the questionnaire for instructors (Addendum 2); others would be obtainable from official records. Generally, however, the cost analysis procedures previously referenced should be the primary guide for the kinds of cost-related measures needed.

Design of the Evaluation

The training device is the independent variable of primary concern. Hence, the focus for the evaluation is on the comparison of the training effectiveness of various RPF devices with corresponding AETs, and when they are available, the comparison of alternative RPF devices. Important to these comparisons are the effects of using the devices (including AETs) in lock-step as opposed to self-paced programs. In addition, the effectiveness of each device for trainees of different aptitude levels or amounts of relevant experience is of concern. Hence, data should be collected that permit meaningful comparisons of device effectiveness separately by instructional mode and by these trainee characteristics.

Assignment of trainees. These comparisons require that separate training groups be established for each device-instructional mode combination. Within each group, all levels of trainee characteristics are to be represented. (See Figure D-1 below for graphic representation of the design.) A parent group of trainees at each training site should be stratified according to aptitude and/or experience levels, and then assigned randomly from within each stratum to the various training programs. Matching of trainees within strata prior to assignment should be avoided, however, because matching would introduce correlations among training groups that would unduly complicate the analyses.

Assignment of instructors. Potentially, the greatest difficulty in interpreting data from an evaluation study as proposed here is the confounding of instructor and program/device effects. Instructors are not likely to be equally effective for a given type of program, nor will a given instructional mode device that is superior when used by one instructor be necessarily superior when used by another. Hence, instructors must be assigned in such a way that their unique effects can be safely ignored in the analyses.

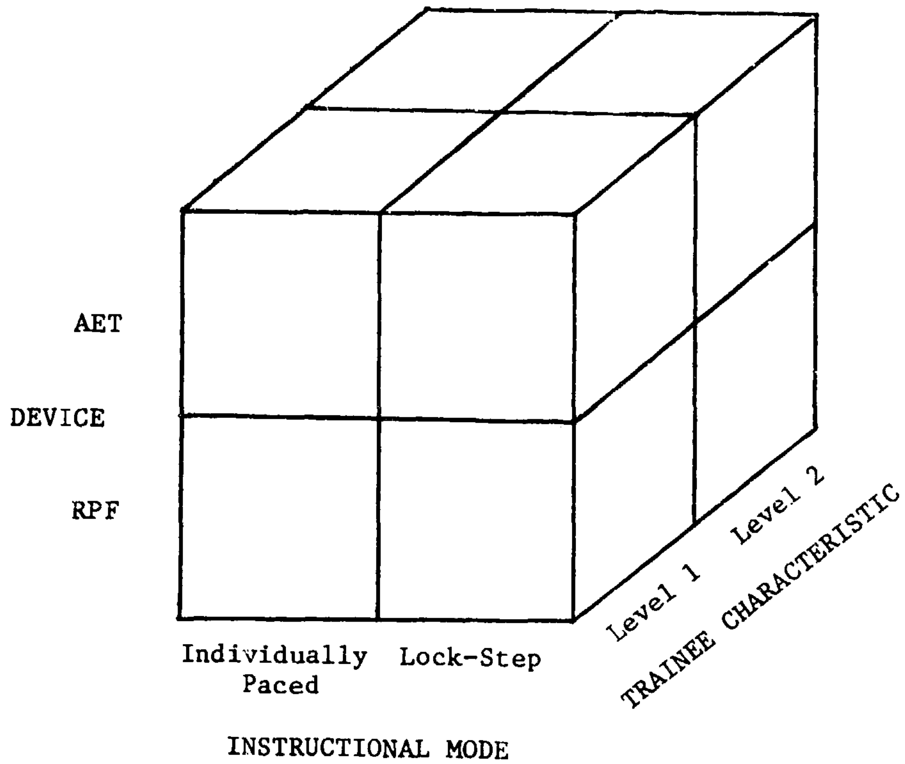

Figure D-1. Basic ANOVA design for analyzing device evaluation data.

One such assignment procedure would require a pool of instructors from which individuals could be drawn for random assignment to the various training programs. Each instructor would participate in only one program, but each program would have multiple instructors for multiple groups of trainees. Combined instructor-program effects on trainee achievement would then be randomized across training classes. Unless training site differences can be safely ignored or controlled statistically, this assignment procedure would not be practicable except at individual sites that had several instructors available for multiple classes in two or more types of programs.

A second procedure for controlling for instructor effects would entail the use of each instructor in each local program. Instructors would then comprise an additional dimension in the basic ANOVA design (see above), and their unique influences could be determined directly and used as needed in interpreting achievement data.

It is possible that neither procedure for assigning instructors can be followed completely, at least at all training locales. If such be the case, interpretations of achievement data may not be clear cut, regardless of significance levels of statistical tests. Also, the assignment of some, but not all, instructors to different programs would result in some between-group correlations of achievement data that would have to be recognized during data analyses.

Standardization of training. Ideally, the training program used with each device should be tailored to capitalize maximally on the training potential of the device. Such optimum training conditions will not have been established empirically at the time of the original device evaluations. Hence, those responsible for the evaluations must ensure that device use conforms to applicable principles of learning technology. With the exception immediately following, a standard training regimen should thus be established for each type of device which incorporates device training characteristics in an effective manner.

The exception just referred to concerns differences in the instructional modes, which are of considerable importance in the evaluation. For any device, dual regimens will be required, one for lock-step and one for individually paced instruction. However, except for differences entailed by the modes per se, the dual regimens should be identical.

In order to provide meaningful bases for comparisons, once a regimen is established for a given device and mode, the investigators should ensure that all instructors using the device faithfully follow the prescribed training regimen.

Collection of data. Achievement data should be collected on each trainee at the end of AIT, and during AIT as relevant data are available. After approximately two months of unit assignment following AIT, job performance data for each trainee should be obtained from job supervisors and otherwise as discussed above. In addition, trainee performance on the Skill Qualification Test, normally taken six months after unit assignment, will provide additional data regarding knowledge and skill levels, and some aspects of job performance.

User acceptance data should be obtained from trainees immediately following AIT, and again from them and from job supervisors approximately two months following unit assignment. Similar data should be obtained from instructors at the end of the AIT course used in the evaluations. Also at that time, the information discussed above regarding characteristics and utilization of training devices could be obtained from the instructors.

Table D-1 presents a schedule for obtaining these measures. The measures are identified only as general classes. The subsection above describing measures to be obtained identifies subclasses of each general type.

Table D-1

Schedule for Obtaining Measures

CLASS OF MEASURE	During AIT	End of AIT	Two Months post-AIT	Six Months post-AIT (SQT)
AIT Achievement/Retention:				
Equipment knowledge	X	X	X	X
Procedural knowledge	X	X	X	X
Hands-on skills	X	X	X	X
User Acceptance by:				
Trainee		X	X	
Instructor		X		
Supervisor			X	
Device Characteristics/Use		X	X	

Analysis of Data

Questions 3, 4 and 5 on page D-4 concerned, respectively, the comparative effectiveness of RPF devices and AETs, their effectiveness when used with different instructional modes, and their effectiveness as dependent upon certain student characteristics. The basic analytic design presented below provides for direct determination of answers to those questions.

The basic design is a three-way analysis of variance (ANOVA) as shown in Figure D-1 above. One dimension of this schema provides for comparisons of the media of primary concern, i.e., AET and one or more RPF devices. Although only a single RPF device is represented in the figure, if comparable data are available for two RPF devices, a second RPF row can be added to the Device classification. On the other hand, when data are available for only one type of media, this dimension will not appear in the analysis.

Columns in the ANOVA model identify types of instructional mode such as lock-step or self-paced instruction. Since the adaptability of a device to the self-paced instructional mode is of considerable concern in the present context, this dimension of the analysis is of considerable importance. However, here too, it may be that data for more than two, or only one, mode are available in particular instances. In such cases, the dimension can be extended or collapsed as described for the Device dimension.

The third dimension of the basic design represents levels of trainee characteristics. When the necessary data are available, trainees should be classified according to level of aptitude scores, or according to amount of previous relevant experience. (Stratification of trainees according to both aptitude and experience levels would require an additional Trainee Characteristic dimension in the basic design.) Only two levels for a single type of characteristic are shown, but it would be desirable to have four if trainee variability is sufficiently great.

The primary concern in this evaluation is the relative effectiveness of alternative devices used in training, whether different RPFs or AETs. The ANOVA provides for such comparisons overall, i.e., regardless of instructional mode or trainee characteristic, as well as comparisons of device effectiveness separately by instructional mode and/or trainee characteristic.

The complexity of the basic design should be increased in some instances, or other classifications or dimensions substituted for those shown in Figure D-1, to provide additional information needed to understand device effectiveness. Two likely dimensions are discussed below.

Repeated measures of trainee achievement. One such dimension would provide for repeated measures of a similar kind on the same trainees. Repeated measures are needed to answer questions regarding patterns of change in trainee achievement over time, and as related to devices used in training. For example, retention of knowledge and skills after unit assignment may well vary with type of device used in training, together with level of trainee characteristic and/or instructional mode. Hence, identical measures taken at the end of AIT and after 2 months of unit experience would comprise two classifications in a repeated measures dimension. Patterns of training group means of these measures could reveal differential retention according to type of training device used and/or its joint effects with instructional mode and student characteristic.

Progress during AIT may also vary with devices used, instructional mode, and trainee characteristics. Successive measures of given types of achievement could thus be made during AIT and analyzed as repeated measures. Information regarding device effects would be analogous to that in the preceding paragraph.

Training site. Another dimension that may need to be added to the basic design, or replace one in the design, is the training locale. Training programs at different sites, or under AIT as opposed to unit administration, can thus be compared. However, because in such instances random assignments of trainees cannot be made from a single parent group as discussed above, it will be especially important to stratify trainees according to both aptitude and experience levels, thus providing two dimensions of trainee characteristics. The double stratification would ensure comparability of trainees on at least two sets of characteristics. Results of such analyses will not be as definitive as random assignments from a single parent group would permit, but cautiously interpreted they could still provide insights into device effects not otherwise available.

This basic design, with extensions as described, is to be used for all dependent data in a suitable metric. The design can be adapted to chi square or other nonparametric analyses for dependent measures of categorical nature. Generally, only two- and three-dimensional chi square tables would be used, with one or two of the dimensions drawn from the ANOVA model and the second or third from score categories.

SUPPORT PERSONNEL

Seven types of technical capabilities must be represented on the team that conducts the training evaluations. These capabilities are:

1. Expertise in administering training program evaluations;

2. Expertise in job/task analyses and in deriving training requirements from them;

3. Expertise in training course design, with special emphasis on training device utilization;

4. Expertise in developing measuring instruments;

5. Expertise in experimental design, especially the adaptation of design requirements to varying local training conditions;

6. Expertise in data analysis in general, and in ANOVA and chi square analyses in particular; and

7. Technical expertise in subject matter.

ADDENDA TO APPENDIX D

Three addenda to Appendix D follow. Each is a specimen questionnaire designed to elicit information regarding training on gasoline engine maintenance and repair. The first Addendum is a questionnaire for trainees, the second is for their instructors, and the third is for job supervisors of graduate trainees. Preceding the questionnaires is a specimen form for providing data required by the Privacy Act of 1974. Properly completed, a copy of this form would accompany each questionnaire.

DATA REQUIRED BY THE PRIVACY ACT OF 1974
(5 U.S.C. 552a)

TITLE OF FORM	PRESCRIBING DIRECTIVE
	AR 70-1

1. AUTHORITY

2. PRINCIPAL PURPOSE(S)

The data collected with the attached form are to be used for research purposes only.

3. ROUTINE USES

This is an experimental personnel data collection form developed by

pursuant to its research mission as prescribed in .
When identifiers (name or Social Security Number) are requested they are to be used for administrative and statistical control purposes only. Full confidentiality of the responses will be maintained in the processing of these data.

Signature

4. MANDATORY OR VOLUNTARY DISCLOSURE AND EFFECT ON INDIVIDUAL NOT PROVIDING INFORMATION

Your participation in this research is strictly voluntary. Individuals are encouraged to provide complete and accurate information in the interests of the research, but there will be no effect on individuals for not providing all or any part of the information. This notice may be detached from the rest of the form and retained by the individual if so desired.

FORM · Privacy Act Statement - 26 S

1. Specimen Trainee Questionnaire for Evaluating Training for The Maintenance and Repair of Gasoline Engines

The purpose of this questionnaire is to determine how you feel regarding your training and ability to maintain and repair gasoline engines. Four types of information are covered. First, there are questions asking how well prepared you feel you are to do the maintenance and repairs on gasoline engines that are expected of you. A second group of questions asks how you feel about the type of training equipment you used to learn gasoline engines during AIT training. A third group of questions asks how you feel overall about the portion of the training program that covered gasoline engines. The remaining questions ask how you feel about your AIT engine training in general, and about a few general aspects of your job.

This questionnaire seems long. However, almost all questions can be answered by either making a circle around a word or number, or placing an X in a blank. There are only very few questions which ask you to write answers, and then very brief answers are all that are necessary.

Please consider carefully and answer all questions that apply to you. In the few cases where written answers are asked for, please take the trouble to write them. Your considered judgments and thoughtful answers are needed for the improvement of the Army's training of maintenance personnel.

Trainee's name:____

I. The purpose of this part of the questionnaire is to determine how well prepared you are at this time to do the tasks required for engine maintenance. Listed below are a number of these tasks. For each task, please circle the number on the right under the column head that you feel best describes your ability to perform each task. The column heads are explained below:

1. Not prepared: means that you have either not learned how to do this task, or have not learned it well enough to try it.

2. Need close supervision: means that you can do this task, but only with close supervision.

3. Need minimum supervision: means that you can do this task fairly well, but you need to consult with someone else at some point for directions or for checking results.

4. Need no supervision: means that you can complete the task without help.

Task	Not prepared	Need close supervision	Need minimum supervision	Need no supervision
(Separate engine maintenance and repair tasks are to be listed here. Examples are: Adjusting a carburetor; Disassembling/reassembling a carburetor; Using a timing light.)	1	2	3	4

II. [1] The purpose of this part of the questionnaire is to determine how much you have improved in task performance since assignment to your unit. The tasks listed below are the same as shown in Part I. above. This time, however, you are to describe how you have

[1] This part would appear only in questionnaires administered after unit assignment. It would be omitted in the one given at the end of AIT.

changed in your ability to do the tasks since you were assigned to this unit. For each task, please circle the number on the right that best describes your improvement. If you needed little or no improvement in performing a given task, that is, if you could do the task when first assigned about as well as it can be done, please place an X in the column headed "No improvement needed." Also, circle a number for "Less able" or "Equally able" for this task to indicate whether you have maintained this skill. The other column headings are explained below:

1. Less able: means that, because of lack of practice or for any other reason, you cannot do this task now as well as you could when you were first assigned to this unit.

2. Equally able: means that you can do this task as well (no better, no worse) as when you were first assigned to this unit.

3. Some improvement: means that you can do this task better than you could when you were first assigned to this unit. For example, you can do the task more rapidly, more efficiently, with fewer errors, etc.

4. Considerable improvement: means that you can do this task considerably better than you could when you were first assigned to this unit

Task	No improvement needed	Less able	Equally able	Some improvement	Considerable improvement
(Tasks will be identical to those listed in Part I.)		1	2	3	4
		1	2	3	4
		1	2	3	4

III. The two parts [1] of the questionnaire above were concerned with your ability to do actual hands-on tasks with engines. The purpose of this part of the questionnaire is to determine how much you know about how engines work and what can go wrong with them. Listed below are several kinds of knowledge. For each subject or kind, please circle

[1] See footnote for Part II.

the number under the column head that you feel best describes your knowledge of that subject. The column heads are explained below.

1. Little or no knowledge: means that you know so little about this subject that you are not even sure what all the words mean that are used to talk about it.

2. Some knowledge: means that you know enough about this subject to understand generally what may be said about it, but you cannot explain it to someone else or answer many questions about it.

3. Quite a bit of knowledge: means that you know enough about this subject to understand fully what may be said about it, and can also explain much of it to someone else and answer co-worker's usual questions about it.

4. Full knowledge: means that you can explain this topic fully to someone else and answer all questions about it that a co-worker is likely to ask.

Kind of knowledge	Little or no knowledge	Some knowledge	Quite a bit of knowledge	Full knowledge
(Separate aspects of engine theory and functioning are to be listed here. Examples are: Valve operations during stroke cycles; How the carburetor mixes fuel and air; Causes of bearing wear; Symptoms of incorrect timing.)	1	2	3	4

IV. 1/ The purpose of this part of the questionnaire is to determine how much you have improved in your knowledge of how engines work and what can go wrong with them since your assignment to your unit. The kinds of knowledge listed below are the same as those in Part III. above.

1/This part would appear only in questionnaires administered after unit assignment. It would be omitted in the one given at the end of AIT.

This time, however, you are to describe how you have changed in your knowledge about engines since you were assigned to your unit. For each kind of knowledge, please circle the number on the right that best describes your improvement. If you needed little or no improvement in knowledge when you were first assigned to your unit, that is, if you knew about as much as you needed to know about the subject, please place an X in the column headed "No improvement needed." Also, circle the number for "Know less" or "Equally able" for that kind of knowledge to indicate whether you remember this knowledge. The other column headings are explained below.

1. Know less: means that you have forgotten more than you have learned about this kind of knowledge since you were first assigned to this unit.

2. No change: means that you know as much (no more, no less) about this subject now as when you were first assigned to this unit.

3. Some improvement: means that you now know somewhat more about this subject than you did when you were first assigned to this unit.

4. Considerable improvement: means that you now know a great deal more about this subject than you did when you were first assigned to this unit.

Kind of knowledge	No Improvement needed	Know less	No change	Some Improvement	Considerable Improvement
(Kinds of knowledge will be the same as in Part III.)		1	2	3	4
		1	2	3	4
		1	2	3	4

V.-A. [1] The purpose of this part of the questionnaire is to determine how you feel about the training equipment used for your AIT training on gasoline engines. In your AIT course on engines, you were taught using (to be completed for each type of RPF device). Please answer the questions below about this device. How you are to answer each question is explained.

How useful was the (device) for training you about engines? (Check one.)

_____It helped me a lot

_____It helped me, but I could have learned more with a real engine

_____It did not help me much at all

If the (device) helped, how did it help you? (Check as many as apply.)

_____It did not help me much at all

_____It helped me understand how engines work

_____It helped me understand what I must do to repair and maintain engines

What was the (device) best for in helping you learn? (Write in your answer.)______________________________

____

What was taught using the (device) that you feel should have been taught some other way? (Write in your answer.)

____

____

When you were using the (device), did you feel that you:

	(Circle one)		
Understood how to use the (device) to learn what you were supposed to learn?	Yes	No	Uncertain
Understood what was being taught with it?	Yes	No	Uncertain

[1] This part will be used only for those trainees who were taught in AIT using an RPF device for engine training.

Were helped in reaching course objectives? Yes No Uncertain

Were learning fast enough? Yes No Uncertain

Had enough information about how well you were doing? Yes No Uncertain

Were making good use of your time? Yes No Uncertain

Would you prefer that most or all of the time you spent using a (device) be spent instead on a real engine? Yes No Uncertain

If you were just now starting the AIT course you went through, would you want to use this (device) again? Yes No Uncertain

If Yes or Uncertain, what changes should be made? (Write in your answer.)____

____

V.-B. 1/ The purpose of this part of the questionnaire is to determine how you feel about the equipment used for AIT training on gasoline engines. In your AIT course on engines, you were taught using an engine (to be completed, describing how engine was mounted, etc.) Please answer the questions below. How you are to answer each question is explained.

How useful was the engine for training you about engines? (Check one.)

_____It helped me a lot

_____It helped me, but I could have learned more using something else

_____It did not help me much at all

If the engine helped, how did it help you? (Check as many as apply.)

_____It did not help me much at all

_____It helped me understand how engines work

_____It helped me understand what I must do to repair and maintain engines

_____It helped me learn to do actual "hands-on" work with engines

---

1/This part will be used only for those trainees who will be taught in AIT using an actual engine for training.

What was the engine best for in helping you learn? (Write in your answer.)

____

____

What was taught using the engine that you feel should have been taught some other way? (Write in your answer.) ______________________________

____

When you were using the engine, did you feel that you:

	(Circle one)		
Understood how to use the engine to learn what you were supposed to learn?	Yes	No	Uncertain
Understood what was being taught with it?	Yes	No	Uncertain
Were helped in reaching course objectives?	Yes	No	Uncertain
Were learning fast enough?	Yes	No	Uncertain
Had enough information about how well you were doing?	Yes	No	Uncertain
Were making good use of your time?	Yes	No	Uncertain

Would you prefer that most or all of the time you spent using an engine be spent instead on other kinds of equipment?	Yes	No	Uncertain
If you were just now starting the AIT course you went through, would you want to use an engine like this again?	Yes	No	Uncertain
Would you want to change the way the engine was used in teaching?	Yes	No	Uncertain

If Yes or Uncertain, what changes should be made? (Write in your answer.)

____

____

VI.-A. 1/ In AIT you went through what is called a lock-step training program on gasoline engines where you and your classmates usually studied everything together, and all students started and ended each part at the same time. In some programs, each student is allowed to advance at his own rate.

1/This part of the questionnaire will be used only for those trainees who were taught about engines in a lock-step program.

The purpose of this part of the questionnaire is to determine how you feel about your lock-step program.

In general, was the pace of the engine part of the course (check one blank)

_____Too fast for you?

_____Too slow for you?

_____About right for you?

Were there some topics you would have liked more time on? (Check one blank.)

_____Yes

_____No

_____Uncertain

If your answer to the last item was Yes or Uncertain, what topics might have needed more time? (Write in your answer.)________________________________

____

Were there some topics which too much time was spent on? (Check one blank.)

_____Yes

_____No

_____Uncertain

If your last answer was Yes or Uncertain, what topics really needed less time? (Write your answer.)________________________________

____

Did you feel that you learned as much as you should have about:

	(Circle one)		
How engines work	Yes	No	Uncertain
How you are to go about repairing or maintaining an engine	Yes	No	Uncertain
How you can do the actual "hands-on" jobs you will need to do?	Yes	No	Uncertain
Did your AIT program give you all the time you needed to learn what you were supposed to learn about engines?	Yes	No	Uncertain

VI.-B. [1] In AIT you went through what is called self-paced training on gasoline engines where you and other students advanced at your own rates. In some programs all students usually studied everything together, and all students started and ended each part at the same time. The purpose of this part of the questionnaire is to determine how you feel about your self-paced program.

In general, was the pace of the engine part of the course: (check one blank)

_____Too fast for you?

_____Too slow for you?

_____About right for you?

Were there some topics you would have liked more time on? (Check one blank.)

_____Yes

_____No

_____Uncertain

If your answer to the last item was Yes or Uncertain, what topics might have needed more time? (Write in your answer.)____

____

Were there some topics which too much time was spent on? (Check one blank.)

_____Yes

_____No

_____Uncertain

If your last answer was Yes or Uncertain, what topics really needed less time? (Write your answer.)____

____

Did you feel that you learned as much as you should have about:

	(Circle one)		
How engines work?	Yes	No	Uncertain
How you are to go about repairing or maintaining an engine?	Yes	No	Uncertain
How you can do the actual "hands-on" jobs you will need to do?	Yes	No	Uncertain

---

[1]This part of the questionnaire will be used only for those trainees who were taught about engines in a self-paced program.

Did your AIT program give you all the time you needed to learn what you were supposed to learn about engines?	Yes	No	Uncertain

VII. The purpose of this part of the questionnaire is to give you an opportunity to express your feelings about your AIT training in general. Please answer each question as it applies to you.

Do you feel that you can do the tasks listed in Part I. above as well as you can be expected to do them at this point in your career? (Check one.)

_____Yes

_____No

_____Uncertain

If your answer was No or Uncertain, which tasks do you feel you were not prepared for as well as you should have been? (Please write your answer, referring to the list in Part I. as necessary.)

____

____

____

____

What changes should be made in the AIT training program to help it provide the engine training necessary at this stage? (Place an X in the blank beside each change you feel should be made.)

_____No change needed

_____More time is needed for AIT training

_____Less time is needed for AIT training

_____More equipment hands-on training is needed

_____The AIT training equipment should be improved

_____The AIT training equipment should be used more

_____More theory of how engines operate should be covered

_____Less theory of how engines operate should be covered

_____More AIT training time should be spent on how to do maintenance tasks

_____Less AIT training time should be spent on how to do maintenance tasks

____The AIT training should be different (different in what way?)

____

____

____AIT training should go deeper into some topics (which topics?)

____

____

In terms of your ability to work with engines that you should have at this stage in your career, what do you feel you are especially well prepared to do? ______________________________________

____

What are you especially weak in regarding engines? ______________

____

VIII. All in all, how valuable was the training equipment used for teaching you about engines in AIT? (Check one blank.)

____Very valuable

____Valuable, but it could have been better

____Of some value, but a lot of improvement is needed

____Of no value

____Uncertain

All in all, how valuable was your AIT training on engines? (Check one blank.)

____Very valuable

____Valuable, but it could have been better

____Of some value, but a lot of improvement is needed

____Of some value

____Uncertain

Regardless of AIT training, what is your overall impression of your present ability to maintain and repair engines? (Check one blank.)

_____Very well qualified

_____Adequately qualified

_____Barely qualified

_____Not qualified

How much confidence do you have in your ability to maintain and repair engines? (Check one.)

_____I feel sure I can do a good job on almost any task

_____I feel I can do a good job most of the time

_____I feel I cannot do a good job most of the time

_____I feel that I am not able to do the job required of me

How do you feel about your maintenance job? (Check one.)

_____I am very enthusiastic; I enjoy my job very much

_____I am happy enough with my job, but sometimes I do not enjoy it

_____I am not content with my job, but I make the best of it

_____I am very dissatisfied with my job; I should be doing something else

Please use the space below, or backs of pages if needed, to write comments that will help in finding out how valuable your AIT training on engines was. You can also use this space is you wish to comment on the questions you have answered.

2. Specimen Instructor Questionnaire for Evaluating Training for the Maintenance and Repair of Gasoline Engines

The purpose of this questionnaire is to determine how you feel regarding the ability of a typical graduating AIT trainee to maintain and repair gasoline engines, and regarding his AIT training to maintain and repair engines. Five types of information are covered. First, there are questions asking how well prepared you feel the trainee is to do the maintenance and repairs on gasoline engines that are expected of him. A second group of questions asks how you feel about his knowledge of engines. A third group of questions asks you to evaluate certain aids used in teaching engines. A fourth group asks you to evaluate certain ways of teaching engines. Finally, the remaining questions focus on AIT training in general.

This questionnaire seems long. However, almost all questions can be answered by either making a circle around a word or number, or placing an X in a blank. There are only very few questions which ask you to write answers, and then very brief answers are all that are necessary.

Please consider carefully and answer all questions about which you have sufficient information. In the few cases where written answers are asked for, please take the trouble to write them. Your considered judgments and thoughtful answers are needed for the improvement of the Army's training of maintenance personnel.

Instructor's name: ______________________________

I. The purpose of this part of the questionnaire is to determine how well prepared the typical trainee is, upon completing AIT, to do the tasks required for engine maintenance. Listed below are a number of these tasks. For each task, please circle the number on the right under the column head that you feel best describes the trainee's ability to perform each task. The column heads are explained below:

1. Not prepared: means that the typical graduating trainee either has not learned how to do this task, or has not learned it well enough to try it.

2. Needs close supervision: means that the typical trainee can do this task, but only with close supervision.

3. Needs minimum supervision: means that the typical trainee can do this task fairly well, but he needs to consult with someone else at some point for directions or for checking results.

4. Needs no supervision: means that the typical trainee can complete the task without help.

   Insufficient information: means that you have not had enough opportunity to observe trainees to rate their performance on a given task. If this is true for a given task, place an X in this column opposite that task.

Task	Not prepared	Needs close supervision	Needs minimum supervision	Needs no supervision	Insufficient information
(Separate engine maintenance and repair tasks are to be listed here.	1	2	3	4	
Examples are: Adjusting a carburetor; Disassembling/reassembling a carbure-	1	2	3	4	
tor; Using a timing light.)	1	2	3	4	

II. The part of the questionnaire above was concerned with the typical graduating trainee's ability to do actual hands-on tasks with engines. The purpose of this part of the questionnaire is to determine how much the typical trainee knows about how engines work and what can go wrong with them. Listed below are several kinds of knowledge. For each subject or kind, please circle the number under the column head that you feel best describes the typical trainee's knowledge of that subject.

The column heads are explained below.

1. Little or no knowledge: means that the typical graduating trainee knows so little about this subject that he is not even sure what all the words mean that are used to talk about it.

2. Some knowledge: means that the typical trainee knows enough about this subject to understand generally what may be said about it, but he cannot explain it to someone else or answer many questions about it.

3. Quite a bit of knowledge: means that the typical trainee knows enough about this subject to understand fully what may be said about it, and can also explain much of it to someone else and answer co-workers' usual questions about it.

4. Full knowledge: means that the typical trainee can explain this topic fully to someone else and answer all questions about it that a co-worker is likely to ask.

Insufficient information: means that you have not had enough opportunity to observe trainees to rate their knowledge on this subject. If this is the case for a given subject, place an X in this column opposite that subject.

Kind of knowledge	Little or no knowledge	Some knowledge	Quite a bit of knowledge	Full knowledge	Insufficient information
(Separate aspects of engine theory and functioning are to be listed here.	1	2	3	4	
Examples are: Valve operations during stroke cycles; How the car-	1	2	3	4	
buretor mixes fuel and air; Causes of bearing wear; Symptoms of incorrect	1	2	3	4	
timing.)	1	2	3	4	

III. 1/ The purpose of this part of the questionnaire is to determine how you feel about the training equipment you have used in AIT training on gasoline engines. In your AIT courses on gasoline engines, you have used (identification of an RPF to be inserted.)

Please answer the questions below about this device. How you are to answer each question is explained.

How much experience have you had with this teaching device? (Check one.)

_____ I have used it only once

_____ I have used it more than once, but no more than three times

_____ I have used it more than three times

How useful was this device for engine training? (Check one.)

_____ It helped a lot

_____ It helped, but more could have been learned using a real engine

_____ It did not help much at all

If the device helped, how did it help? (Check as many as apply.)

_____ It did not help much at all

_____ It helped teach how engines work

_____ It helped teach what must be done to repair and maintain engines

_____ It helped teach actual "hands-on" work with engines

What was the device best for in helping trainees learn? (Write in your answer.) ________________________________

____

What was taught using the device that you feel should have been taught some other way? (Write in your answer.) ________________________

____

1/ This section of the questionnaire is to be repeated for each RPF device used. If an instructor has not used such a device, this section would be omitted from his questionnaire.

When you were using the device, did you feel <u>that the trainees</u>:

	(Circle one)		
Understood how to use the device to learn what they were supposed to learn?	Yes	No	Uncertain
Understood what was being taught with it?	Yes	No	Uncertain
Were helped in reaching course objectives?	Yes	No	Uncertain
Were learning fast enough?	Yes	No	Uncertain
Had enough information about how well they were doing?	Yes	No	Uncertain
Were making good use of their time?	Yes	No	Uncertain

When you were using the device did you feel <u>that the device</u>:

	(Circle one)		
a. Was easy to set up for teaching?	Yes	No	Uncertain
b. Was easy for an instructor to use after setup?	Yes	No	Uncertain
c. Was easy for the trainees to use?	Yes	No	Uncertain
d. Provided for evaluations of enough different types of student performance?	Yes	No	Uncertain
e. Provided rapid enough feedback to trainees regarding how they were doing?	Yes	No	Uncertain
f. Had the software needed to capitalize adequately on the device's training potential?	Yes	No	Uncertain
g. Was dependable in that it did not require an undue amount of maintenance and repair?	Yes	No	Uncertain
h. Provided for teaching a good range of subject matter?	Yes	No	Uncertain
i. Provided ample opportunity for trainees to practice without undue supervsion by you?	Yes	No	Uncertain
j. Had sufficient fidelity to actual engines for teaching purposes?	Yes	No	Uncertain

You will note that the questions just preceding regarding device characteristics are identified by letters a. through j. You may have circled No or Uncertain for one or more of them. If so, please use the space below to state why you did not feel, or were uncertain, that this characteristic is satisfactory for this device. For each No or Uncertain circled, please identify the corresponding letter in the space below and state briefly after the letter what you consider needs improvement in the device. If more space is needed, you may write on the back of this page.

____

____

____

____

____

____

____

____

____

____

____

____

Would you want to change the way this device is used in teaching? Yes No Uncertain

What changes should be made? (Write in your answer.)______________________

____

If you were free to choose, would you use this device in all similar courses? Yes No Uncertain

If you circled No or Uncertain, what would you prefer instead of this device? (Check both if you would prefer either to this device.)

_____A real engine

_____Another device (which one?)______________________________________

IV. 1/ The purpose of this part of the questionnaire is to determine how you feel about some actual engine equipment you have used in AIT training on gasoline engines. In your AIT courses on gasoline engines, you have used (identification of an AET configuration, including definition of AET, to be inserted).

Please answer the questions below about this AET. How you are to answer each question is explained.

How much experience have you had with this AET? (Check one.)

_____I have used it only once

_____I have used it more than once, but no more than three times

_____I have used it more than three times

How useful was this AET for engine training? (Check one.)

_____It helped a lot

_____It helped, but more could have been learned using another type of teaching aid

_____It did not help much at all

If the AET helped, how did it help? (Check as many as apply.)

_____It did not help much at all

_____It helped teach how engines work

_____It helped teach what must be done to repair and maintain engines

_____It helped teach actual "hands-on" work with engines

What was the AET best for in helping trainees learn? (Write in your answer.)____

____

What was taught using the AET that you feel should have been taught some other way.? (Write in your answer.)

____

____

1/This section of the questionnaire is to be repeated for each basically different AET configuration used. If an instructor has not used AETs, this section would be omitted from his questionnaire.

When you were using the AET, did you feel that the trainees:

	(Circle one)		
Understood how to use the AET to learn what they were supposed to learn?	Yes	No	Uncertain
Understood what was being taught with it?	Yes	No	Uncertain
Were helped in reaching course objectives?	Yes	No	Uncertain
Were learning fast enough?	Yes	No	Uncertain
Had enough information about how well they were doing?	Yes	No	Uncertain
Were making good use of their time?	Yes	No	Uncertain

When you were using the AET did you feel that the AET:

	(Circle one)		
a. Was easy to set up for teaching?	Yes	No	Uncertain
b. Was easy for the instructor to use after set-up?	Yes	No	Uncertain
c. Was easy for the trainees to use?	Yes	No	Uncertain
d. Provided for evaluations of enough different types of student performance?	Yes	No	Uncertain
e. Provided rapid enough feedback to trainees regarding how they were doing?	Yes	No	Uncertain
f. Was dependable in that it did not require an undue amount of maintenance and repair?	Yes	No	Uncertain
g. Provided for teaching a good range of subject matter?	Yes	No	Uncertain
h. Provided ample opportunity for trainees to practice without undue supervision by you?	Yes	No	Uncertain
i. Had sufficient fidelity to functional engines in vehicles for teaching purposes?	Yes	No	Uncertain

You will note that the questions just preceding regarding AET characteristics are identified by letters a. through i. You may have circled No or Uncertain for one or more of them. If so, please use the space below to state why you did not feel, or were uncertain, that this characteristic is satisfactory for this AET. For each No or Uncertain circled, please identify the corresponding letter in the space below and state briefly after the letter what you consider needs improvement in this AET. If more space is needed, you may write on the back of this page.

____

____

____

____

____

____

____

____

____

____

____

____

Would you want to change the way this AET is used in teaching? Yes No Uncertain

What changes should be made: (Write in your answer.) ____________________

____

If you were free to choose, would you use this AET in all similar courses? Yes No Uncertain

If you circled No or Uncertain, what would you prefer instead of this AET? (Check both if you would prefer either to this AET.)

_____A different AET (which one?)______________________________

_____An engine simulator designed for teaching (which one?)__________

____

V. 1/ In AIT you taught in what is called a lock-step training program on gasoline engines where trainees usually studied everything together, and all students started and ended each part at the same time. (In some programs, each student is allowed to advance at his own rate.) The purpose of this part of the questionnaire is to determine how you feel about the lock-step program.

In general, was the pace of the engine part of the course (check one blank)

_____Too fast for the typical trainee?

_____Too slow for the typical trainee?

_____About right for the typical trainee?

Were there some topics you would have liked to spend more time on? (Check one blank.)

_____Yes

_____No

_____Uncertain

If your answer to the last item was Yes or Uncertain, what topics might have needed more time? (Write in your answer.)________________________

____

Were there some topics which too much time was spent on? (Check one blank.)

_____Yes

_____No

_____Uncertain

If your last answer was Yes or Uncertain, what topics really needed less time? (Write your answer.)____

____

1/This part of the questionnaire will be used only for those instructors who taught engines in a lock-step program.

Did you feel that the typical trainee learned as much as he should have about:

	(Circle one)		
How engines work?	Yes	No	Uncertain
How he is to go about repairing or maintaining an engine?	Yes	No	Uncertain
How he can do the actual "hands-on" jobs he will need to do?	Yes	No	Uncertain
Did the lock-step AIT program give him all the time he needed to learn what he was supposed to learn about engines?	Yes	No	Uncertain

VI. [1] In AIT you taught in what is called a self-paced training program on gasoline engines where students advanced at their own rates. (In some other programs all students usually studied everything together, and all students started and ended each part at the same time.) The purpose of this part of the questionnaire is to determine how you feel about the self-paced program.

In general, was the pace of the engine part of the course (check one blank)

_____Too fast for the typical trainee?

_____Too slow for the typical trainee?

_____About right for the typical trainee?

Were there some topics you would have liked to spend more time on? (Check one blank.)

_____Yes

_____No

_____Uncertain

If your answer to the last item was Yes or Uncertain, what topics might have needed more time? (Write in your answer.)________________________

____

[1] This part of the questionnaire will be used only for those instructors who taught engines in a self-paced program.

Were there some topics which too much time was spent on? (Check one blank.)

_____Yes

_____No

_____Uncertain

If your last answer was Yes or Uncertain, what topics really needed <u>less</u> time? (Write your answer.)____________________________

____

Did you feel that the typical trainee learned as much as he should have about:

	(Circle one)		
How engines work?	Yes	No	Uncertain
How he is to go about repairing or maintaining an engine?	Yes	No	Uncertain
How he can do the actual "hands-on" jobs he will need to do?	Yes	No	Uncertain
Did the self-paced AIT program give him all the time he needed to learn what he was <u>supposed</u> to learn about engines?	Yes	No	Uncertain

VII. The purpose of this part of the questionnaire is to give you an opportunity to express your feelings about AIT training in general. Please answer each question as it applies to you.

Do you feel that the typical graduating trainee can do the tasks listed in Part I. above as well as he <u>can be expected to do them at this point in his career</u>? (Check one.)

_____Yes

_____No

_____Uncertain

If your answer was No or Uncertain, which tasks do you feel the typical trainee is <u>not prepared for as well as he should be</u>. (Please write your answer, referring to the list in Part I. as necessary.)

____

____

____

____

What changes should be made in the AIT training program to help it provide the engine training necessary at this stage? (Place an X in the blank beside each change you feel should be made.)

_____No changes needed

_____More time is needed for AIT training

_____Less time is needed for AIT training

_____More equipment hands-on training is needed

_____The AIT training equipment should be improved

_____The AIT training equipment should be used more

_____More theory of how engines operate should be covered

_____Less theory of how engines operate should be covered

_____More AIT training time should be spent on how to do maintenance tasks

_____Less AIT training time should be spent on how to do maintenance tasks

_____The AIT training should be different (different in what way?)

____

____

_____AIT training should go deeper into some topics (which topics?)

____

____

In terms of the capabilities with engines that the typical trainee should have at this stage in his career, what do you feel he is especially well prepared to do? ______________________________

____

What is he especially weak in regarding engines? ________________

____

VIII. All in all, how valuable was the training equipment used for teaching about engines in AIT? (Check one blank.)

_____Very valuable

_____Valuable, but it could have been better

_____Of some value, but a lot of improvement is needed

_____Of no value

_____Uncertain

All in all, how valuable is AIT training on engines? (Check one blank.)

_____Very valuable

_____Valuable, but it could have been better

_____Of some value, but a lot of improvement is needed

_____Of no value

_____Uncertain

Regardless of AIT training, what is your overall impression of a graduating trainee's ability to aintain and repair engines? (Check one blank.)

_____Very well qualified

_____Adequately qualified

_____Barely qualified

_____Not qualified

Whether or not the typical trainee is realistic, how much confidence does he have in his ability to maintain and repair engines? (Check one.)

_____Feels sure he can do a good job on almost any task

_____Feels he can do a good job most of the time

_____Feels he cannot do a good job most of the time

_____Feels that he is not able to do the job required of him

Are the typical trainee's feelings about his ability realistic? That is, does he show overconfidence, too little confidence, or just the right amount? (Check one.)

_____Shows overconfidence; he is not as good as he thinks he is

_____Shows too little confidence; he is better than he thinks he is

_____He is realistic in his feelings about his ability

How does the typical trainee feel about his job? (Check one.)

_____Seems very enthusiastic; seems to enjoy his job very much

_____Seems happy enough with his job, but sometimes seems not to enjoy it

_____Seems discontented with his job, but makes the best of it

_____Seems very dissatisfied with his job; he should be doing something else

Please use the space below, or backs of pages if needed, to write comments that will help in finding out how valuable A T training on engines is. You can also use this space if you wish to comment on the questions you have answered.

3. Specimen Supervisor Questionnaire for Evaluating Training for the Maintenance and Repair of Gasoline Engines

This questionnaire concerns the mechanic identified below. The purpose of the questionnaire is to determine how you feel regarding his ability to maintain and repair engines. Three types of information are covered. First, there are questions asking how well prepared you feel the mechanic is to do the maintenance and repairs on gasoline engines that are expected of him. A second group of questions asks how you feel about his knowledge of engines. The remaining questions focus on the mechanic's AIT training in general and a few general aspects of his job performance.

This questionnaire seems long. However, almost all questions can be answered by either making a circle around a word or number, or placing an X in a blank. There are only very few questions which ask you to write answers, and then very brief answers are all that are necessary.

Please consider carefully and answer all questions about which you have sufficient information. In the few cases where written answers are asked for, please take the trouble to write them. Your considered judgments and thoughtful answers are needed for the improvement of the Army's training of maintenance personnel.

Mechanic being rated: ______________________________

Rater's name: ______________________________

I. The purpose of this part of the questionnaire is to determine how well prepared the mechanic is at this time to do the tasks required for engine maintenance. Listed below are a number of these tasks. For each task, please circle the number on the right under the column head that you feel best describes the mechanic's ability to perform each task. The column heads are explained below:

1. Not prepared: means that the mechanic has either not learned how to do this task, or has not learned it well enough to try it.

2. Needs close supervision: means that the mechanic can do this task, but only with close supervision.

3. Needs minimum supervision: means that the mechanic can do this task fairly well, but he needs to consult with someone else at some point for directions or for checking results.

4. Needs no supervision: means that the mechanic can complete the task without help.

Insufficient information: means that you have not had enough opportunity to observe the mechanic to rate his performance on a given task. If this is true for a given task, place an X in this column opposite that task.

Task	Not prepared	Needs close supervision	Needs minimum supervision	Needs no supervision	Insufficient information
(Separate engine maintenance and repair tasks are to be listed here.	1	2	3	4	
Examples are: Adjusting a carburetor; Disassembling/reassembling a carburetor;	1	2	3	4	
Using a timing light.)	1	2	3	4	

II. The purpose of this part of the questionnaire is to determine how much the mechanic has improved in task performance since his assignment to your unit. The tasks listed below are the same as those in Part I. above. This time, however, you are to describe how the mechanic has changed in ability to do the tasks since he has been assigned to this unit. For each task, please circle the number on the right that best describes his improvement. In the event that the mechanic needed little or no improvement in performing a given task, that is, he could do the task at the outset about as well as it can be done, please place an X in the column headed "No improvement needed." Also, circle a number for "Less able" or "Equally able" for this task to indicate whether the mechanic has maintained this skill. The other column headings are explained below:

1. Less able: means that, because of lack of practice or for any other reason, the mechanic cannot do this task now as well as he could when he was first assigned to this unit.

2. Equally able: means that the mechanic can do this task as well (no better, no worse) as when he was first assigned to this unit.

3. Some improvement: means that the mechanic can do this task better than he could when he was first assigned to this unit. For example, he can do the task more rapidly, more efficiently, with fewer errors, etc.

4. Considerable improvement: means that the mechanic can do this task considerably better than he could when he was first assigned to this unit.

Insufficient information: means that you have not had enough opportunity to observe the mechanic to rate his performance on a given task. If this is true for a given task, place an X in this column opposite that task.

Task	No improvement needed	Less able	Equally able	Some improvement	Considerable improvement	Insufficient information
(Tasks will be identical to those listed in Part I.)		1	2	3	4	
		1	2	3	4	
		1	2	3	4	

III. The two parts of the questionnaire above were concerned with the mechanic's ability to do actual hands-on tasks with engines. The purpose of this part of the questionnaire is to determine how much the mechanic knows about how engines work and what can go wrong with them. Listed below are several kinds of knowledge. For each subject or kind, please circle the number under the column head that you feel best describes this mechanic's knowledge of that subject. The column heads are explained below.

1. Little or no knowledge: means that the mechanic knows so little about this subject that he is not even sure what all the words mean that are used to talk about it.

2. Some knowledge: means that the mechanic knows enough about this subject to understand generally what may be said about it, but he cannot explain it to someone else or answer many questions about it.

3. Quite a bit of knowledge: means that the mechanic knows enough about this subject to understand fully what may be said about it, and can also explain much of it to someone else and answer co-workers' usual questions about it.

4. Full knowledge: means that the mechanic can explain this topic fully to someone else and answer all questions about it that a co-worker is likely to ask.

Insufficient information: means that you have not had enough opportunity to observe the mechanic to rate his knowledge on this subject. If this is the case for a given subject, place an X in this column opposite that subject.

Kind of knowledge	Little or no knowledge	Some knowledge	Quite a bit of knowledge	Full knowledge	Insufficient information
(Separate aspects of engine theory and functioning are to be listed	1	2	3	4	
here. Examples are: Valve operations during stroke cycles; How the carburetor	1	2	3	4	
mixes fuel and air; Causes of bearing wear; Symptoms of incorrect timing.)	1	2	3	4	

IV. The purpose of this part of the questionnaire is to determine how much the mechanic has improved in his knowledge of how engines work and what can go wrong with them since his assignment to your unit. The kinds of knowledge listed below are the same as those in Part III. above. This time, however, you are to describe how the mechanic has changed in his knowledge about engines since he was assigned to your unit. For each kind of knowledge, please circle the number on the right that best describes his improvement. If the mechanic needed little or no improvement in knowledge when he was first assigned to your unit, that is, if he knew about as much as he needs to know for his job, please place an X in the column headed "No improvement needed." Also, circle the number for "Knows less" or "Equally able" for that kind of knowledge to indicate whether the mechanic has retained this knowledge. The other column headings are explained below.

1. Knows less: means that the mechanic has forgotten more than he has learned about this kind of knowledge since he was first assigned to this unit.

2. No change: means that the mechanic knows as much (no more, no less) about this subject now as when he was first assigned to this unit.

3. Some improvement: means that the mechanic now knows somewhat more about this subject than he did when he was assigned to this unit.

4. Considerable improvement: means that the mechanic now knows a great deal more about this subject than he did when he was first assigned to this unit.

Insufficient information: means that you have not had enough opportunity to observe the mechanic to evaluate his improvement in knowledge of this subject. If this is the case for a given subject, place an X in this column opposite that subject.

Kind of knowledge	No improvement needed	Knows less	No change	Some improvement	Considerable improvement	Insufficient information
(Kinds of knowledge will be the same as in Part III.)		1	2	3	4	
		1	2	3	4	
		1	2	3	4	

V. The purpose of this part of the questionnaire is to give you an opportunity to express your feelings about this mechanic's AIT training in general. Please answer each question as it applies to this mechanic.

Do you feel that this mechanic can do the tasks listed in Part I, above as well as he <u>can be expected to do them at this point in his career</u>? (Check one.)

_____Yes

_____No

_____Uncertain

If your answer was No or Uncertain, which tasks do you feel he was not prepared for as well as he should have been? (Please write your answer.)

____

____

____

What changes should be made in the AIT training program to help it provide the training necessary at this stage? (Place an X in the blank beside each change you feel should be made. If you are not familiar with some aspects of AIT training covered below, simply leave the blank unmarked.)

_____No changes needed

_____More time is needed for AIT training

_____Less time is needed for AIT training

_____More equipment hands-on training is needed

_____The AIT training equipment should be improved

_____The AIT training equipment should be used more

_____More theory of how engines operate should be covered

_____Less theory of how engines operate should be covered

_____More AIT training time should be spent on how to do maintenance tasks

_____Less AIT training time should be spent on how to do maintenance tasks

_____The AIT training should be different (different in what way? ____

____

_____AIT training should go deeper into some topics (which topics?) ______________________________________

____

_____Less AIT training time should be spent on some topics (which topics?)___________________________________

____

In terms of the capabilities this mechanic should have at this stage in his career, what do you feel he is especially well prepared to do?____

____

What is he especially weak in?________________________

____

____

VI. All in all, how valuable was the training equipment used for teaching this mechanic about engines in AIT? (Check one blank.)

_____Very valuable

_____Valuable, but it could have been better

_____Of some value, but a lot of improvement is needed

_____Of no value

_____Uncertain

All in all, how valuable was this mechanic's AIT training on engines? (Check one blank.)

_____Very valuable

_____Valuable, but it could have been better

_____Of some value, but a lot of improvement is needed

_____Of no value

_____Uncertain

Regardless of AIT training, what is your overall impression of this mechanic's present ability to maintain and repair engines? (Circle one.)

_____Very well qualified

_____Adequately qualified

_____Barely qualified

_____Not qualified

Whether or not the mechanic is realistic, how much confidence does he have in his ability to maintain and repair engines? (Check one.)

_____Feels sure he can do a good job on almost any task

_____Feels he can do a good job most of the time

_____Feels he cannot do a good job most of the time

_____Feels that he is not able to do the job required of him

Are the mechanic's feelings about his ability realistic? That is, does he show overconfidence, too little confidence, or just the right amount? (Check one.)

_____Shows overconfidence; he is not as good as he thinks he is

_____Shows too little confidence; he is better than he thinks he is

_____He is realistic in his feelings about his ability

How does this mechanic feel about his job? (Check one.)

_____Seems very enthusiastic; seems to enjoy his job very much

_____Seems happy enough with his job, but sometimes seems not to enjoy it

_____Seems discontented with his job, but makes the best of it

_____Seems very dissatisfied with his job; he should be doing something else

Please use the space below, or backs of pages if needed, to write comments that will help in finding out how valuable AIT training on engines is. [1/] You can also use this space if you wish to comment on the questions you have answered.

[1/] This information is needed only once from each supervisor.